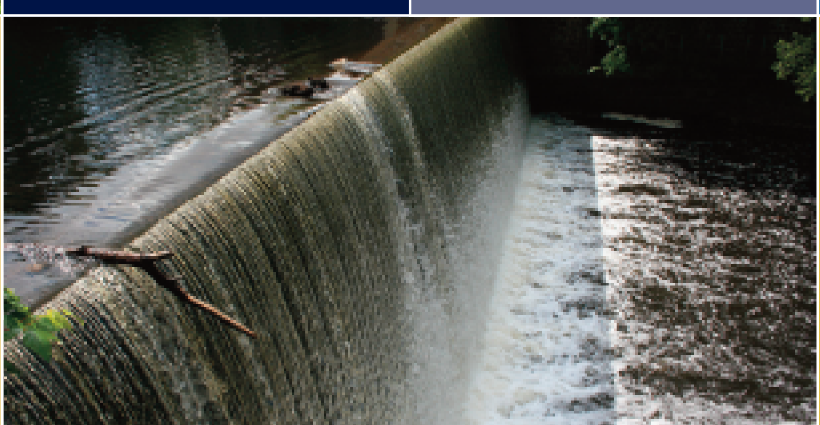
R.I. RENEWABLE ENERGY SITING PARTNERSHIP
FINAL REPORT

VOLUME 1
SUMMARY REPORT

RESP



RENEWABLE ENERGY SITING PARTNERSHIP

VOLUMES I AND II

CREDITS

The Renewable Energy Siting Partnership document is a product of the 2011 Memorandum of Understanding between the Rhode Island Office of Energy Resources, then directed by Kenneth Payne, and the University of Rhode Island.

The RESP document was created under the management of Principle Investigators Marion Gold, URI Outreach Center and Jennifer McCann, URI CRC/RISG.

Management Team

To demonstrate the University of Rhode Island's commitment to the RESP project, Dr. John Kirby, Dean of the College of the Environment and Life Sciences (CELS), and David M. Farmer, Dean of the Graduate School of Oceanography appointed the following people to oversee all aspects of the RESP:

Marion Gold, URI Outreach Center
Jennifer McCann, CRC/RISG
Dennis Nixon, URI GSO
Richard Rhodes, Ph.D., URI CELS

ACKNOWLEDGEMENTS

The State of Rhode Island Office of Energy Resources gratefully acknowledges the extensive time, energy, and thought the following committed individuals dedicated to the creation of the Rhode Island Renewable Energy Siting Partnership Final Report:

Project Team

Marion Gold, team lead, URI Outreach Center
Jennifer McCann, team lead, CRC/RISG
Michelle Carnevale, CRC/RISG
Teresa Crean, CRC/RISG
Sue Kennedy, CRC/RISG
Helen Manning, CRC
Danny Musher, URI Outreach Center
Amber Neville, CRC/RISG
Sarah Schumann
Rachel Sholly, URI Outreach Center
Chip Young, URI CI

Research Team

Senior Advisor: Malcolm Spaulding, Ph.D., URI DOE
Annette Grilli, Ph.D., URI DOE
John Merrill, Ph.D., URI GSO
Peter Paton, Ph.D., URI
Gopu Potty, Ph.D., URI DOE
James Opaluch, Ph.D., URI CELS
Sarah Butler, URI
Thomas Boving, Ph.D., URI CELS
Pamela Cady, URI CELS
Christopher Damon, URI
Tiffany Davis, URI
Corrie Heinz, URI
Kelly Knorr, URI
James H. Miller, URI
Danny Musher, URI Outreach Center
Edson Okwelum, URI ENRE
Christopher O'Reilly, URI

Research Finance and Support Team

Kate Manning Butler, CRC/RISG
Mike Milkman, URI Outreach Center

Technical Team

Environmental Data Center, Department of Natural Resources Science at URI:
Peter August
Christopher Damon
Tiffany-Lane Davis
Charles LaBash

Consultants

10up LLC
Applied Science Associates, Inc.
Environment Northeast

Roger Williams University Sea Grant Law Fellows and Faculty

Susan Farady, Director, Marine Affairs Institute, Director, RISG Legal Program
Julia Wyman, Staff Attorney, Marine Affairs Institute
Sarah Parker
Scott R. Gunst, Jr.
Kaitlin Sweeney
Brandon Biggs

URI Outreach Center Energy Fellows

Nathan Brown
Kristina DiSanto
Alexa Fedorchak
Eric Kretsch
Cara Nunez
Christopher Caisse
Sarah Martin
Sabrina Ulmasova

State Agency Assistance and Coordination

RI Coastal Resources Management Council
RI Department of Environmental Management
RI Economic Development Corporation
RI Office of Energy Resources
RI Office of the Governor
RI Department of Administration, Division of Planning, Statewide Planning Program

Government Agency Review

Robert Ballou, RI DEM
James Boyd, CRMC
Barbara Cesaro, RI OER
Kevin Flynn, RI SPP
Paul Gonsalves, RI SPP
Nancy Hess, RI SPP
Christopher Kearns, Office of the Governor
Hannah Morini, RI EDC
Kenneth Payne, RI OER
Jared Rhodes, RI SPP

TECHNICAL ADVISORY COMMITTEE MEMBERS

Acoustics

Jim Cummings, Acoustic Ecology Institute
Peter McPhee, Massachusetts Clean Energy Center
Ken Kaliski, Resource Systems Group, Inc.

Avian and Bat

Eugenia Marks, Rhode Island Audubon Society
Rhonda Smith, USFWS
Charlie Brown, RI DEM

Economics

Abigail Anthony, Ph.D, Environment Northeast
Bogdan Prokopovych, College of Business Administration, URI

Thomas Grigalunas, Ph.D, Professor Emeritus of Environmental and Natural Resource Economics, URI
Timothy Tyrrell, Ph.D, School of Community Resources and Development, ASU

Hydropower and Hydropower Resource

Guy Lefebvre, RI Rivers Council
Rachel Calabro, Save the Bay
Jon Petrillo, The Essex Partnership, LLC.
Art Gold, Ph.D, Watershed Hydrology, URI
Douglas Hall, Idaho National Laboratory Wind and Water Program
Alisa Richardson, RI DEM Office of Water Resources
Catherine Sparks, RI DEM

Landfill Solar

Mark Dennen, RI DEM Landfill Closure Program
Palmer Moore, NEXAMP, Inc.
Alan Benevides, Woodard & Curran, Inc.

RI Energy.Org

Abigail Anthony, Ph.D, Environment Northeast
Mike Guerard, Optimal Energy, Inc.
Stephan Wollenburg, Energy Consumers Alliance of New England

Shadow Flicker

Ken Kaliski, Resource Systems Group, Inc.
Peter McPhee, Massachusetts Clean Energy Center

Wind Energy Chapter

Malcolm Spaulding, Ph.D, URI Engineering
Tyler Studds, Massachusetts Clean Energy Center
Stephan Wollenburg, Energy Consumers Alliance of New England

Wind Power Modeling and Siting

John Merrill, Ph.D, URI Graduate School of Oceanography
Tyler Studds, Massachusetts Clean Energy Center

Wind Resource Assessment

Annette Grilli, Ph.D, URI Engineering
Peter McPhee, Massachusetts Clean Energy Center

RESP Public Engagement

The RESP stakeholder and public engagement process brought together a diverse and well-rounded group of key constituencies by reaching out to two core groups of people simultaneously. The first group included organizations deemed to be essential in developing and implementing renewable energy siting strategies in the state, including municipalities, relevant state and federal agencies, regional planning councils, non-governmental organizations, chambers of commerce, historical societies, universities, tourism groups, utilities, land trusts, and the Narragansett Indian Tribe. The second key group was self-selecting, and included members of the public and the business community. Both groups were indispensable to creating a transparent and objective RESP process meeting the needs of all Rhode Islanders.

Municipal Working Group

The RESP Team acknowledges and appreciates the contributions of the municipal representatives who attended the six Municipal Working Group meetings between October 2011 and March 2012. Attendees included town planners, town managers, and town council members from all of Rhode Island's 39 cities and towns, as well as representatives from regional planning councils. Sessions, which took place at the University of Rhode Island Bay Campus, were open to the public but targeted towards the needs of municipal planners and decision makers.

RESP Stakeholder Group

Residents, Citizens, and Members of the RI Public that engaged in the public stakeholder process throughout the 16–month-long course of the RESP.

3 Sisters Design
Alteris Renewables
Apex Wind
Applied Science Associates
Aquidneck Island Land Trust
Aquidneck Island Planning Commission
Audubon Society of Rhode Island
Barrington Renewable Energy Committee
Blackstone River Watershed Council
Block Island Power Company
Bristol Wind Power
Bryant University
Chariho Middle School
Conanicut Energy
Conservation Law Foundation
Cranston Public Schools
CurveWater LLC
Deep Blue Technologies
Department of Environmental Management
DeWayne Allen Associates
Division of Planning
E2SOL LLC
EA Engineering
East Bay Energy Consortium
East Providence Fuel Oil Company
Endless Energy
Energy Consumers Alliance of New England
Environment Northeast
Environmental Council of RI
ESS Group
Essex Partnership
Fall River Mill Owners Association
Filarski/ architecture + planning + research
Grubb and Ellis Real Estate
Guardian Fuel and Energy
NERC Renewables
Newport Energy and Environment Commission
Newport Harbor Corporation
Newport Solar
Newport Waterfront Events
NEXAMP
North Kingstown High School
Northeast Sustainable Energy Association
Ocean State Clean Cities

Office of Energy Resources
People's Power and Light
Point Energy Solutions
Providence Water Supply Board
Real Goods Solar
Representative Larry Ehrhardt
Representative Teresa Tanzi
Rhode Island School of Design
Rhode Power
RI Land Trust Council
RI Rivers Council
Roger Williams University
rTerra
Save the Bay
Schneider Electric
Senator Jack Reed
Solar Canopy LLC
Soltas Energy
SPG Renewables
Stillwater Preservation Conservancy
Tech Comm Partners
The Nature Conservancy
U.S. Department of Agriculture
U.S. Fish and Wildlife Service
U.S. Navy
University of Rhode Island
VHB
Washington County Regional Planning Council
Wind Energy Development LLC
Wood-Pawcatuck Watershed Association
Woonasquatucket River Watershed Council

DOA SPP Wind Advisory Committee (2010 – 2012)

A committee formed to help the Rhode Island Division of Planning, Statewide Planning Program develop a set of wind energy siting guidelines.

Jeff Broadhead, Washington County Regional Planning Council
Lisa Bryer, Town of Jamestown
Julian Dash, RI Economic Development Corporation
Thomas Getz, (Retired) RI Department of Environmental Management
Daniel Goulet, Coastal Resources Management Council
Gary Gump, Town of Portsmouth
Amy Kullenberg, Conservation Law Foundation
Bruce Long, Town of Middletown
Karina Lutz, People's Power and Light
Daniel Mendelsohn, Applied Science Associates
Colin O' Sullivan, North Kingstown Resident
Kenneth Payne, (Retired) RI Office of Energy Resources
Garry Plunkett, East Bay Wind Consortium
Jon Reiner, Town of North Kingstown
Andrew Shapiro, Apex Wind
Larry Taft, Audubon Society of Rhode Island
Barry Wenskowicz, Narragansett Bay Commission

Hydropower Working Group

A working group comprised of academics, state and federal agencies, non-profit and environmental groups, and others all with expertise in issues surrounding hydropower development in Rhode Island. The group contributed to the formation of RIDEM's Draft Guidance on Siting Considerations for Development of New Hydropower Facilities.

Mark Amaral, Lighthouse Consulting Group
Tom Ardito, Narragansett Bay Estuary Program
Rachel Calabro, Save the Bay
Bruce DiGennaro, The Essex Partnership
Marion Gold, URI
Melissa Grader, US F&W
Sue Kiernan, RIDEM
Amy Kullenberg, Conservation Law Foundation
Guy Lefebvre, RI Rivers Council
Hannah Morini, RIEDC
Danny Musher, URI
Jon Petrillo, The Essex Partnership
Alisa Richardson, RIDEM
Cathy Sparks, RIDEM

LIST OF ACRONYMS

AC	Alternating Current
ALP	Alternative Licensing Process
APE	Area of Potential Effect
ATM	Applied Technology and Management
AWEA	American Wind Energy Association
BGEPA	Bald and Golden Eagle Protection
BOS	Balance of System
CEC	California Energy Commission
CEEP	Center for Energy, Economic, and Environmental Policy
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Information System
CLF	Conservation Law Foundation
CRC	Coastal Resources Center
CRMC	Coastal Resources Management Council
CWA	Clean Water Act
CWIF	Caithness Wind Information Forum
CZMA	Coastal Zone Management Act
DAB	Digital Audio Broadcasting
DC	Direct Current
DEC	Department of Environmental Conservation
DEM	The Department of Environmental Management
DHAC	Division of Hydropower Administration and Compliance
DMD	dam management district
DOE	Department of Energy
DSSMP	Dam Safety Surveillance and Monitoring Plan Outlines
EA	Environmental Assessment
EBEC	East Bay Energy Consortium
ECN	Energy Research Center of the Netherlands
EERE	Office of Efficiency and Renewable Energy
EFH	essential fish habitat
EIA	Energy Information Administration
EIS	Environmental Impact Statement
ELUs	Ecological Land Units
EMD	Energie-og Miljødata
EMI	Electromagnetic interference
EPA	Environmental Protection Agency
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration

FAA	Federal Aviation Administration
FDC	flow duration curve
FERC	Federal Energy Regulatory Commission
FM	Frequency Modulation
FPA	Federal Power Act
FT	Federally Threatened
HCP	Habitat Conservation Plan
HPMP	Historic Properties Management Plan
HSWA	Hazardous and Solid Waste Amendments
IEA	International Energy Association
ILP	Integrated Licensing Process
IPCC	Intergovernmental Panel on Climate Change
ISET	Institut für Solare Energieversorgungstechnik
ISO	Independent System Operation New England
ITP	Incidental Take Permit
kW	kilo watts
L&Rr	Landfill And Resource Recovery
LCP	Landfill Closure Program
LIHI	Low Impact Hydropower Institute
MA DEP	Massachusetts Department of Environmental Protection
MA DPH	Massachusetts Department of Public Health
MBTA	Migratory Bird Treaty Act
MOU	Memorandum of Understanding
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MW	mega watts
NATHPO	National Association of Tribal Historic Preservation Officers
NBEP	Narragansett Bay Estuary Program
NCSHPO	National Conference of State Historic Preservation Officers
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NITHPO	Narragansett Indian Tribal Historic Preservation Office
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent to File a License
NPL	National Priority List
NPS	National Park Service
NREL	National Renewable Energy Laboratory
NWCC	National Wind Coordinating Committee
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
Ocean SAMP	Ocean Special Area Management Plan

OER	Office of Energy Resources
ORV	Outstanding Remarkable Value
OSWER	Office of Solid Waste and Emergency Response
PAD	Pre-Application Document
PV	Photovoltaic
RCRA	Resource Conservation and Recovery Act
REC	Renewable Energy Certificate
RERL	Renewable Energy Research Lab
RES	Renewable Energy Standard
RESP	Renewable Energy Siting Partnership
RHA	Rivers and Harbors Act
RI DEM	Rhode Island Department of Environmental Management
RIDEC	R.I. Economic Development Council
RIDEM	Rhode Island Department of Environmental Management
RIEDC	Rhode Island Economic Development Council
RIGIS	Rhode Island Geographic Information System
RIHP&HC	Rhode Island Historical Preservation and Heritage Commission
RINHP	Rhode Island Natural Heritage Program
RIPUC	Rhode Island Public Utilities Commission
RIRRC	Rhode Island Resource Recovery Corporation
SC	State Species of Concern
SDM	Streamflow Depletion Methodology
SEC	Solar Energy Cover
SHPO	State Historic Preservation Officer
SIWP	Site Investigation Work Plan
SODAR	Sonic Detection and Ranging Instrument
SPP	The Statewide Planning Program
ST	State Threatened
THPO	Tribal Historic Preservation Officer
TLP	Traditional Licensing Process
TMDL	Total Maximum Daily Load
TMY	Typical Meteorological Year
UHF	Ultra High Frequency
URI	University of Rhode Island
USACE	United States Army Corps of Engineers
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WQC	water quality certification

RENEWABLE ENERGY SITING PARTNERSHIP

VOLUME I. SUMMARY REPORT

Table of Contents

Executive Summary

In recent years, Rhode Island has experienced mounting interest in in-state development of renewable energy. This trend is visible both on the ground, with the introduction of new renewable energy projects, and at the policy level, with the enactment of new renewable energy policies. As technologies like wind energy, solar energy, and hydropower gain momentum in this small and densely populated state, residents and decision makers are striving to make planning and siting decisions that optimize local renewable energy opportunities while balancing these benefits with other public and private priorities, such as quality of life, public safety, and environmental protection. In this endeavor, it is vital that Rhode Islanders have access to the best available information about opportunities and constraints shaping renewable energy development in the state.

The Renewable Energy Siting Partnership (RESP) is a state-wide renewable energy resource assessment and siting analysis in Rhode Island that blends a worldwide literature review, state-specific original research, and an extensive stakeholder engagement process to help Rhode Islanders evaluate and plan for renewable energy in their communities. Commissioned by the Office of Energy Resources (OER) and led by the University of Rhode Island (URI), the RESP was a 16-month process designed to promote informed and collaborative decision-making about renewable energy in Rhode Island.

Insights gained through the RESP are designed to enrich local deliberations about whether to pursue renewable energy opportunities, where to site renewable energy projects, and how to mitigate any negative impacts caused by these projects. The RESP engaged scientists, policy makers, and the public in examining these questions for each of three categories of renewable energy in Rhode Island:

1. Onshore wind energy projects between 100 kW and 1.5 MW;
2. Low-head hydroelectric power facilities on preexisting dams in Rhode Island; and
3. Solar power facilities 1 MW or greater located on closed landfills.

While the applicable permitting entities and issues of concern are different for each of these forms of energy, the objectives of the RESP were the same: to synthesize a range of information and resources, and to make this information available to stakeholders and decision makers through a variety of user-friendly and informative decision support tools.

The RESP Process

The RESP drew on a rich knowledge base, bringing together information from across the globe and Rhode Island-specific data and insights. URI's Outreach Center and Coastal Resources Center/Rhode Island Sea Grant led the process, compiling data on renewable energy impacts from elsewhere in the world, overseeing original research by URI scientists, spearheading an extensive stakeholder and public engagement process, and coordinating a technical and public review phase to validate the accuracy and completeness of the RESP document.

Scientific analysis: Original research by URI scientists contributed valuable estimations regarding the availability, distribution, and potential impacts of wind, solar, and hydropower resources in Rhode Island. Models developed by URI scientists supported the following aspects of the RESP:

- Development of a statewide wind energy siting methodology for identifying favorable wind energy locations and appropriate practices to minimize possible adverse impacts on surrounding communities and habitats;
- Calculation of hydropower production potential at 57 existing dams across Rhode Island and identification of environmental, socioeconomic, and regulatory constraints relevant to hydropower development; and
- Development of a screening methodology to support identification of landfill sites favorable for solar energy development, and approximations of solar production potential at these sites.

Stakeholder and public participation: The RESP stakeholder outreach and public engagement process granted the public a central role in issue identification, information synthesis, and development of final RESP products. Key stakeholder participants included municipalities, state and federal agencies, regional planning councils, non-governmental organizations, chambers of commerce, historical societies, universities, tourism groups, utilities, land trusts, businesses, and the public. The RESP reached out to these groups through a series of monthly general stakeholder meetings, field trips to current renewable energy sites, a traveling lecture series, two targeted hydropower stakeholder workshops, a Renewable Energy Day, a Municipal Working Group, and a Wind Energy Siting Working Group. Through these varied forums for involvement, the public was able to express concerns and make inquiries regarding the effects of new renewable energy in the state, engage in mutual learning with scientists and government officials, and help state agencies incorporate this information into siting guidelines.

State agency consultation: The RESP process was greatly enhanced by two instances of in-depth collaboration with state agencies. In the first instance, the RESP team partnered with the Department of Administration, Division of Planning, Statewide Planning Program to develop a set of guidelines for wind energy systems development in Rhode Island. As part of this collaboration, the RESP team and the Statewide Planning Program (SPP) partook in a continuous exchange of knowledge and dialogue with the stakeholder-based Wind Energy Siting Working Group. The Division also used a small advisory stakeholder committee of its own and together these joint efforts resulted in the document called “Renewable Energy Siting Guidelines, Part 1: Interim Siting Factors for Terrestrial Wind Energy Systems”. These wind siting guidelines were released for public comment with the draft RESP documents in the summer of 2012, however, they are currently undergoing further review by OER and SPP and will not be released with the final RESP document.

In a second instance of extensive collaboration with a state agency, the RESP team joined forces with the Rhode Island Department of Environmental Management (RIDEM) to explore opportunities and constraints affecting hydropower development in Rhode Island. The collaboration between RIDEM and the RESP team strengthened the RESP hydropower analysis and supported the publication of an RIDEM document titled "Management Guidance on Siting Considerations for Development of New Hydropower Facilities," which stands alongside the RESP report as one of the most current and comprehensive accounts of hydropower potential in Rhode Island. As part of this collaboration, RIDEM and the RESP team hosted two joint all-day workshops for hydropower stakeholders. These events not only integrated stakeholder expertise into the RIDEM and RESP processes simultaneously, but enabled stakeholders to articulate desired distinctions between the respective roles of these two projects.

Development of final products: The RESP presents the results of its analysis in two forms. The first is a summary report presenting the results of the RESP scientific research, and findings from other scientific studies that collectively represent the best available knowledge on renewable energy resources in Rhode Island and potential effects of its development. The second is a website containing a collection of resources designed to inform renewable energy planning and siting decisions in the state. This website, available at RI Energy.org, presents energy data, resource mapping tools, impact modeling tools, and other useful information developed and synthesized by the RESP. Together, the RESP report and website represent the most comprehensive resource to-date for citizens, businesses, and government officials contemplating renewable energy in Rhode Island.

Review process: The RESP report and website were strengthened by both a technical review process and a public review process that spanned over ninety days. The comments received during each review phase helped to ensure the RESP documents and online resources were clear and accurate.

WIND ENERGY

Wind energy is a nascent but growing industry in Rhode Island. The state's first large-scale wind turbine began functioning in 2006, and by the time the RESP was concluded in 2012, eleven more turbines had been erected. Yet prior to the RESP, the opportunities and implications of this emergent form of energy in the state remained vague. Drawing on a variety of existing and original spatial and descriptive information, the RESP aimed to help stakeholders and decision makers more clearly visualize the available resources, obstacles, and consequences associated with future wind energy development in Rhode Island.

The RESP wind siting analysis provides a multi-layered mapping process that merges spatial representations of wind speeds and potential wind energy production with overlays depicting an array of siting considerations facing development of wind energy in the state.

Evaluation of wind energy potential relied on modeled and empirical wind speed data, while mapping of constraints drew on existing geospatial datasets maintained by URI's Environmental Data Center. Both were interpreted in conjunction with the RESP's extensive stakeholder engagement process to improve their accuracy and relevance for use in decision making.

The U.S. Department of Energy estimates that wind energy production currently requires wind speeds greater than 7 m/sec (16mph) at 80m (262 ft). As a whole, Rhode Island's average statewide wind speeds at this height are less than that minimum, at 5.5-6.0 meters/sec (12-13 mph) which can be explained by the state's generally low elevation and the presence of forests over much of its inland territory. However, Rhode Island does contain specific areas that may be favorable for wind energy development. RESP maps show that the highest potential for generation of wind energy in Rhode Island lies along the coast, where wind speeds are less affected by drag than in forested regions further inland. Coastal regions of the state experience wind speeds measuring an average of 6.5-7.5 meters/sec (15-17 mph) for the mainland coast and Narragansett Bay islands, and 8-9 meters/sec (18-20 mph) for Block Island. Not surprisingly, most existing wind turbines in Rhode Island at the time of the RESP are located in coastal regions.

Wind resources are not the only factors determining the favorability of a location for wind energy development. In addition to exploring spatial patterns in the wind itself, the RESP mapping process evaluated the spatial distribution of siting considerations or factors that may make wind energy development less practical or desirable. Siting considerations include water bodies, impermeable surfaces (e.g., roads, bridges and parking lots), homes and buildings, legally protected wildlife habitat, airports, communications towers, important bird habitat, areas with recreational, and/or historical significance, and residential neighborhoods where safety, tranquility, and/or aesthetics may be affected in undesirable ways by wind turbines. Although wind energy is not categorically off-limits in areas where these factors are present, site selection or the project review process may be informed by the presence or proximity of certain resources, habitat or infrastructure.

The RESP facilitated identification of concerns at the local level by synthesizing current global and in-state knowledge pertaining to impacts of wind turbines on surrounding communities. The RESP stakeholder engagement process played a key role in vetting this comprehensive synopsis and tailoring it to local conditions. Key RESP findings on potential impacts and mitigation measures relating to wind energy development are presented below.

- *Structural failure*: Structural failure of wind turbines is rare but not impossible. Publically available data on the structural failure rates of wind turbines is limited, and often relates to technology manufactured over a decade ago. However, improvements in technology have likely further reduced the low probability of structural failure. If an entire turbine falls or a stationary blade or blade fragment detaches and drops, the radius of impact is generally limited to a distance equal to the height of the turbine. If a fragment of a blade detaches while the rotor is spinning, the location of landfall is controlled by the angular velocity of the rotor, the position of the breaking point on the blade, and the size of the fragment. Setbacks from residential homes, roads, or other buildings and infrastructure are commonly used to minimize safety concerns from structural failures.

- *Icing:* Icing occurs when water freezes on the surface of turbine blades and other parts. It is important to assure that ice is not thrown from a moving blade in such a way that it injures people and property upon landfall. Rhode Island experiences weather conditions conducive to icing about 0-2 times annually. During those times, there may be a risk of ice throw if a turbine continues to operate. The effects of icing can be minimized through setbacks, temporary shutdown procedures, and ice detection mechanisms.
- *Acoustic impacts:* The operation of wind turbines can produce white noise (also called broadband noise), tonal noise, impulsive noise ("swishing"), low-frequency noise, and infrasound. Turbine noise dissipates with distance from the turbine. At close proximities, wind turbine noise can be considered annoying, and, for some people residing near turbines, has been reported to cause sleep disturbance. However, the level of annoyance and overall impact experienced by people living near a wind turbine or multiple wind turbines varies widely. Moreover, there is a lack of conclusive evidence to date demonstrating adverse health effects associated with wind turbine noise. The level of background noise produced by other activities in the vicinity is an important factor to consider when predicting the acoustic impacts of a wind turbine at a given site. Where ambient noise levels are high, as in densely populated or industrial zones, turbine noise tends to be less noticeable. RESP researchers developed a tool to model the acoustic impacts of a hypothetical wind turbine at any point in Rhode Island; this modeling tool[1] is available at RI Energy.org.
- *Shadow Flicker:* Moving wind turbine blades can cause a flickering shadow effect when positioned within the line of sight between the sun and a viewer. Shadow flicker can be considered annoying and, when frequent, can cause disruption to daily life. It does not, however, induce seizures, as was once hypothesized. Shadow flicker takes place only when the sun is shining. In an average year in Rhode Island, slightly over half of the days each year are sunny or partly sunny. In addition, shadow flicker is visible only during times of the day and the year when the sun is at a low angle in the sky. The area of land which may be affected by shadow flicker in our latitudes will typically be shaped like a bow tie or flattened cross when viewed from above. Using these rules of thumb, RESP researchers developed a tool to model the effects of shadow flicker at any point in Rhode Island; this modeling tool is available at RI Energy.org. Predictive models can be used to establish setback zones that protect nearby residents from the effects of shadow flicker.
- *Electromagnetic signal interference:* Like other tall structures, wind turbines have the potential to interfere with electromagnetic waves, such as those used by television, cell phones, radio, and scanning telemetry systems. Turbines can cause both blocking and reflection of these signals when located in the line of sight between a transmitter and a receiver. For example, many public safety radio systems rely on fixed radio links which could be disrupted if wind turbines are placed within the line of sight between a receiver and transponder, especially those using microwave wavelengths and frequencies in the gigahertz range. Appropriate siting of wind turbines to avoid sight lines of affected technologies will

[1] Utilizing the siting tools on RI Energy.org, a Wind Siting Case Study was created and included in this document as an addendum to the RI Energy.org chapter (RESP Chapter 4).

minimize any possible impacts. Electromagnetic occurrence is less problematic with newer wind turbines than with older ones made of metal.

- *Avian and bat impacts:* The effects of wind turbines on bird and bat populations are highly variable and can be partly controlled through proper siting and mitigation measures, such as stopping or slowing the turbine during migration periods. When in close proximity with turbines, birds and bats may undergo collisions, displacement, and habitat loss; bats can also suffer from barotrauma, a form of internal tissue damage that transpires when bats encounter the sudden low pressure zone created by a spinning turbine rotor. Likelihood of collision varies as a function of species abundance, species behavior, season, location, and turbine characteristics. However, compared to collision rates with buildings and other existing infrastructure, bird collisions with wind turbines are relatively infrequent. Most bird mortalities caused by collision occur during spring and fall migrations, while most bat mortalities occur from mid-summer to fall. Construction of turbines can cause habitat fragmentation, and presence of turbines can lead birds or bats to avoid parts of their territory that are vital for their survival. The four most important habitat types used by birds in Rhode Island are grasslands, scrub-shrub, forests, and coasts. Vulnerable species, such as those on federal and state endangered and threatened species lists, represent a priority concern when siting wind turbines. Two federally listed threatened bird species and one federally listed endangered bat species are known to frequent habitat in Rhode Island. In addition, 53 Rhode Island bird species are listed as endangered, threatened, or of concern by the state. Siting projects to avoid impacting known nests and/or key habitats may minimize negative effects to these vulnerable species.
- *Cultural and historic impacts:* The environment around a proposed wind turbine may contain historic buildings, artifacts, and landscapes; sites of cultural importance to Native American tribes; and places valued for their scenic or recreational value. Such sites are scattered throughout Rhode Island. Wind turbines can cause both direct and indirect effects on historic, cultural, and recreational sites when not sited in a way that respects these established and irreplaceable uses. Many historic and cultural sites are legally protected by the federal National Register of Historic Places, the Rhode Island State Register of Historic Places, municipal historic districts, and/or the Narragansett Indian Tribe Historic Preservation Office. Consultation with the managers of these entities is of the essence when siting new wind turbines in the state.
- *Visual impacts:* Wind turbines with generating power between 100 kW and 1.5 MW are large, often eclipsing in height elements of the surrounding landscape, and as such are frequently visible from a distance. Some viewers find the appearance of wind turbines distasteful, and visual impacts tend to be a common source of concern among neighbors of proposed wind turbines worldwide. The visual effects of wind turbines may be more significant in areas valued for their scenic qualities. In addition, residents who oppose the presence of turbines for non-visual reasons, such as noise impacts or a feeling that they were not adequately consulted in the siting process, tend to have a strong negative reaction to the visibility of turbines. Cumulative impacts stemming from construction of multiple turbines and/or other structures may heighten negative attitudes towards the visual appearance of wind turbines among residents. Visual impacts can be assessed through community review of photographic and computer models that illustrate what a proposed turbine would look like in a given setting.

- *Property Values:* Possible effects of wind turbines on property values are often raised as a concern among community members during the wind turbine siting or review process. Most scientific studies to date have found no measurable effect of wind turbines on home sales prices, but this is not to say that no relationship exists. Notably, all large-scale analyses have so far focused on wind farms, as opposed to isolated turbines; wind farms are far more likely to be located in rural areas at significant distances from their nearest neighbors. More research is needed to further clarify the effects of wind development on property values in contexts like Rhode Island's (i.e., high population density areas, including urban and suburban settings). The relationship between turbines and property values is a high priority for future analysis.

Considerations for Moving Forward

The task of harnessing wind energy potential in Rhode Island is complicated by the fact that the windiest parts of the state tend to also be densely populated or important wildlife habitat. Given the existing uses of these areas, care must be taken to avoid and/or minimize potential negative impacts. Proper siting is the best known antidote to potential negative impacts associated with wind energy development. This conclusion section summarizes the RESP findings, and provides considerations moving forward in the drafting of statewide siting guidelines, or designing municipal review procedures for proposed projects, or wind energy ordinances. It also provides a list of pre-construction assessments and post-construction monitoring studies that a municipality may want to consider when determining what information or data is required during the review and permitting process. In addition, this conclusion section outlines siting or mitigation options that may be used to minimize the impacts of wind energy development.

Through the RESP's review of the best available science, and compiling stakeholder feedback, two areas were identified that would benefit from additional research, especially research specific to Rhode Island: (1) a Rhode Island-centered investigation into the impacts of wind turbines on nearby property values, and (2) Data collection and analysis of the acoustic impacts of operating wind turbines in the state, including infrasound. Research in both of these areas would provide useful information in the development of municipal regulations or statewide wind energy siting guidelines.

HYDROPOWER

The presence of over 742 dams in Rhode Island's waterways is a testament to the state's long and rich history of harnessing water energy. The RESP hydropower analysis assessed opportunities to tap the energy potential of these existing dams by retrofitting them for hydropower production. Although only seven dams are currently licensed to generate electricity (with a collective total capacity of 6.7 MW), interest in developing existing dams for hydropower is growing, as evidenced by the recent proposal of six new facilities of this type. Like the wind energy analysis, the RESP hydropower analysis involved a two-pronged approach that evaluated energy production potential alongside development constraints, assisted by the valuable insights of a wide array of stakeholders.

RESP researchers estimate that Rhode Island's existing dam sites have a potential to generate approximately 21 MW of nameplate power and produce upwards of 90 GWh of energy. These figures were calculated by generating predicted site-specific flow values at the 57 largest existing dam sites in the state, including those dams currently producing electricity. RESP flow value estimates, which were produced by models based on basin relief and drainage area data, represent the most refined calculation of hydropower potential in Rhode Island to date. The RESP estimate is consistent with other studies of hydropower potential in Rhode Island, including a 2012 RIDEM study that estimated potential energy production in the state at 15-20 MW, based on analysis of 326 dams.

According to RESP findings, Rhode Island's hydropower resource is predominately clustered within two rivers and at a handful of dam sites. Much of it is concentrated in the Blackstone River (almost 13 MW estimated nameplate potential) and the Pawtuxet River (about 5 MW estimated nameplate potential). The Wood-Pawcatuck, Ten Mile, and Woonasquatucket rivers account for approximately 2.75 MW of collective estimated nameplate potential. Of the 21 MW total estimated nameplate capacity in the state, 6.7 MW are available at sites already developed for hydropower, 4.8 MW are available at sites currently proposed for hydropower, and 9.2 MW are available at undeveloped sites with no immediate plans for development. By far the largest number of dams (44) fall into this final category, reflecting the fact that most dams in the state have relatively low commercial hydropower potential on a per-site basis compared to those sites already developed or proposed for development.

RESP research identified several possible impacts from hydroelectric generation on downstream habitat and surrounding communities. Existing dams have complex effects on many aspects of river ecology, including oxygen levels, stream flow, and fish passage. Many of these effects can be ecologically detrimental. On the other hand, many Rhode Island's dams are now integral elements of river ecosystems, sustaining valuable wetlands, performing flood control services, and in some cases keeping in check buried contaminants found in sediments upstream. Many have also become part of the historical and recreational fabric of the state. Thus, hydropower development on existing dams in Rhode Island must confront the dual role of dams in both degrading and maintaining river ecosystems. The RESP evaluated these complex interactions through a literature search, extensive collaboration with RIDEM, and a targeted public process that included two all-day workshops with dam and river stakeholders. Key findings are summarized below.

- *Fish passage:* Populations of diadromous fish (i.e., those that migrate between freshwater and marine habitats) have declined significantly since the 19th century, primarily due to the widespread obstruction of rivers by dams. In recent years, RIDEM and other organizations have made significant progress towards restoring fish passage to the Ten Mile, Blackstone, Pawcatuck, Pawtuxet, and Woonasquatucket Rivers. Utmost care must be taken to assure that new hydropower facilities do not reverse this progress. Fish passage restoration can be achieved through dam removal or through installation of fish ladders; hydroelectric additions to existing dams are clearly incompatible with dam removal. If a hydropower tailrace (the channel where water is carried away from a turbine) is placed too close to a fish ladder, it can make this type of fish passage ineffective. But despite these possible conflicts between fish passage restoration and hydropower development, many RESP stakeholder participants also foresee a potential synergy between fish passage restoration and hydropower development on existing dams. In this vision, constructive reuse of dams that have long lain idle may present an opportunity to improve fish passage on Rhode Island rivers by providing additional impetus and new sources of funding for restoration that would otherwise be unavailable. With careful planning and coordination among relevant stakeholders, it may be possible to reconcile the co-location of hydropower with fish passage restoration in a mutually beneficial fashion.
- *Water quality:* Development of hydropower may cause changes in streamflow, dissolved oxygen, temperature, sediments, and wetlands in Rhode Island rivers. When installed on existing dams, hydroelectric turbines tend to result in a removal of dissolved oxygen, because although water flowing over a dam gains oxygen by mixing with air, water passing through a turbine does not interact with air. Sediments collected behind dams can present a serious water quality threat if long-buried contaminants are disturbed or released during modification of a dam for hydroelectric generation. Operation of hydropower facilities can occasionally lead to fluctuations in water flow, causing drying of the river and harm to wildlife. By altering natural water levels within a river, dams can cause changes in water temperature with possible repercussions for aquatic life. Each of these effects is a function of the unique biological and physical conditions present within each river system, and can potentially be controlled through careful pre-development analysis and creation of hydroelectric operating plans customized to the specific environmental conditions present at each dam site.
- *Historical and cultural resources:* Many of Rhode Island's dams played a vital role in the development of the state's culture and economy, and provide visible reminders of the past. Changes in appearance resulting from retrofitting historic dams for hydroelectric purposes may either detract from or add to the historical value of a dam, depending on the frame of reference of the observer and the historical significance of the site. In addition to altering the historic integrity of an old dam itself, retrofitting historic dams for hydropower may indirectly alter the historic value of historic sites adjacent to dams, through introduction of modern equipment into the visual panorama. Dam sites and their environs may be subject to one or more forms of legal protection intended to safeguard their historic or cultural value,

such as the National Register of Historic Places, local historic district ordinances, or regulations pertaining to the John H. Chafee Blackstone River Valley National Heritage Corridor.

- *Recreational considerations:* Many of Rhode Island's waterways are popular destinations for paddling, hiking, swimming, and nature contemplation. Installation of hydropower facilities on existing dams has the potential to alter the recreational value of Rhode Island rivers by obstructing river bank access points, altering water depths needed to support paddling activity, impeding fishing activities in the immediate vicinity of the dam, and adversely affecting fish populations pursued by freshwater anglers. Input from the public and recreational users will assure that new hydropower usage of existing dams does not conflict with established recreational uses of Rhode Island's waterways.
- *Dam safety:* Many dams were constructed at a time when population densities were lower than they are today, and many are now located upstream of neighborhoods and urban centers. Failure of these dams could lead to serious injury, property damage, economic losses, and even loss of life. At sites where impoundment sediments contain contaminants, structural failure can also cause downstream contamination leading to harmful water quality effects. RIDEM has classified 97 dams in Rhode Island as high-hazard (i.e., dam failure would result in loss of human life) and 83 as representing a significant hazard (i.e., dam failure would cause significant economic damage). Some historical dams in Rhode Island may have been neglected over the years, and dam safety must be carefully evaluated and addressed prior to any hydropower construction activities. Obligatory evaluation of dam safety prior to hydropower construction can be seen as an opportunity to address dam safety issues that are currently underfinanced.

SOLAR ENERGY ON CLOSED LANDFILLS

As the second most densely-populated state in the nation, Rhode Island faces geographic limitations on the amount of space available for indigenous energy production. Therefore, if communities choose to develop renewable sources of energy, strategic siting of electricity generation facilities is paramount, particularly with space-intensive technologies requiring flat expanses of open land like solar. In a state like Rhode Island, where space is at a premium, solar energy may be best suited to lands with limited utility for other forms of development. The RESP solar energy analysis focused on one particular category of lands meeting these characteristics in Rhode Island: closed landfills. The goals of the RESP solar energy analysis were to estimate total statewide landfill-based solar energy potential and to perform a detailed screening analysis to identify specific landfills suitable for generating at least 1 MW of solar power.

RESP analysis evaluated 58 closed landfills and estimated that suitably sloped areas (with a gradient less than 6%) on these landfills have a capacity to support a total of 391 MW of solar power. Slope is an important consideration in solar energy siting because steep gradients can pose structural and design challenges for ground-mounted photovoltaic arrays and lead to shading, erosion, and infiltration problems.

However, not all land area meeting slope criteria is available for development. Solar energy installations are generally incompatible with certain established land uses, such as forests or homes. Land use classes most amenable to solar energy development include waste disposal, vacant or barren lands, brushlands, and agricultural lands. After narrowing down landfill acreage to available land area to those portions of closed landfills characterized by these latter land use classifications, the RESP team refined its estimate of solar energy capacity to 110 MW. RESP researchers concluded that out of the 58 closed landfills evaluated, 37 sites could support photovoltaic solar arrays of 1 MW or greater capacity.

Lastly, the RESP classified landfills according to several additional site suitability characteristics identified in partnership with RIDEM. The final product of this analysis is a comprehensive spreadsheet detailing each site in terms of its landfill cap composition, current landfill usage, interconnection feasibility, and ownership status. Ideal landfill sites for solar energy development share a combination of the following characteristics:

- Open acreage with southern exposure
- Few site owners and adequate zoning for solar development
- Critical infrastructure, such as electric distribution lines and access roads, already in place
- Lack of current land use (e.g., recreation) that is incompatible with solar energy development
- Formal closure, proper capping, and minimal remediation required

Managing potential impacts of landfill solar energy development is generally less complex than with other types of renewable energy development, or even comparable solar installations located in more pristine or densely populated areas. Because landfill solar development occurs on property already contaminated by past waste disposal, the maintenance of pristine environmental, visual, aesthetic, cultural, or historical resources is often less challenging. Compliance with a suite of existing regulations can help mitigate principal environmental impacts, such as the effects of stormwater runoff from the landfill, or potential detrimental effects on sensitive elements of the surrounding ecosystem, including endangered species or nearby wetlands.

The primary consideration of developing a landfill site for solar generation is often meeting the technical, design, and compliance challenges of developing a contaminated site. In order for solar development to proceed on a landfill, the site must be formally closed according to standards set by the state solid waste authority—the RIDEM Office of Waste Management Landfill Closure Program (LCP). Achieving compliance with the most recent regulatory standards may require site remediation or capping of waste at the landfill prior to development. These measures ensure that the principal purpose of the landfill site—waste disposal—is maintained in conjunction with the new use of renewable energy generation.

If done properly, developing Rhode Island's landfills for solar electricity generation has the opportunity provide a dual benefit: an increase in power production from renewable sources and the adaptive reuse of fallow land. Additionally, solar development can help leverage funding that might otherwise be unavailable to help communities participate in the Landfill Closure Program. And if a site is properly suitable for development, a landfill once considered to be a public liability can now become a community asset.

Conclusion

RESP findings represent a publicly accessible, centralized collection of information that will enable community members and others to formulate educated opinions about options for renewable energy in their communities. It is hoped that this information will improve development proposals, increase transparency with regard to potential impacts of proposed developments, and make for a collaborative exchange of ideas and information among developers, decision-makers, and community members when deciding whether and where to construct renewable energy facilities in a community.

The intended end users of the RESP products are renewable energy stakeholders in Rhode Island. Municipal decision makers are anticipated to be the primary users of the RESP, but other stakeholders and decision makers, including the public, state officials, the advocacy community, and energy developers, are also expected to make use of RESP findings and tools as they evaluate renewable energy options in areas of interest to them. RESP findings are not intended to supersede any site-specific analyses that would be required for project development or construction. However, RESP findings may be used by developers and decision-makers to make informed preliminary judgments, such as drawing rough comparisons between various locations or narrowing down a list of potential sites.

RENEWABLE ENERGY SITING PARTNERSHIP

INTRODUCTION TO VOLUME I

Table of Contents

Introduction to the Rhode Island Renewable Energy Siting Partnership

In recent years, Rhode Island has witnessed rapid growth in the development of in-state renewable sources of energy.[1] As interest in renewable energy continues to rise, it is imperative that new renewable energy facilities are permitted and sited in a way that balances the benefits of renewable energy with other public and private priorities, such as quality of life, public safety, health, and environmental protection. Due to limited past experience with renewable energy in Rhode Island, possible trade-offs between renewable energy and other priorities are not yet fully understood, and mechanisms to resolve them have not been formally proposed. The Renewable Energy Siting Partnership (RESP) is a first step in filling these gaps.

The RESP was a collaborative process, overseen by the University of Rhode Island (URI), that brought together scientists, decision-makers, and the public to identify and explore issues of importance related to the siting and permitting of new renewable energy facilities in the state. Spanning 16 months, the RESP focused on three specific categories of renewable energy:

1. Onshore wind energy projects between 100 kW and 1.5 MW;
2. Low-head hydroelectric power facilities on preexisting dams in Rhode Island; and
3. Solar power facilities 1 MW or greater, located on closed landfills.

The RESP synthesized the best available knowledge regarding potential power production and possible social and environmental impacts of each of these categories of renewable energy in Rhode Island, and identified important areas of focus for future investigation. RESP findings do not constitute formal policy guidance, but instead offer an informational starting point for decision makers and communities seeking to define appropriate approaches to renewable energy in their respective jurisdictions.

1. Renewable Energy Policy in Rhode Island and Origins of the RESP

State policy makers have long recognized the need for comprehensive siting and planning analysis, backed by sound science and public input, to guide renewable energy development in Rhode Island. For the last decade, two issues—diversifying Rhode Island's fossil fuel-reliant energy mix and meeting expected growth in energy demand using a cleaner energy supply—have driven Rhode Island energy policy. The State's official push to satisfy both of these goals through increased production of renewable sources of energy began with the 2004 enactment of Rhode Island's Renewable Energy Standard, or RES (R.I.G.L. 39-26-1 et seq.). This legislation mandated that Rhode Island meet 16% of its electrical power needs from renewable sources by

[1] At the time of this writing in 2012, Rhode Island contains five hydroelectric facilities, ten commercial-scale land-based wind turbines, and assorted other renewable energy facilities. According to the U.S. Energy Information Administration (2012), in-state renewable energy facilities constitute about 1.6% of Rhode Island's total electrical power generation capacity (measured in megawatts) and net electricity generation from renewable facilities provide enough energy to meet about 1.9% of the state's annual electricity demand (measured in megawatt-hours). Almost all of this renewable generation (1.8%) derives from energy supplied by municipal solid waste/landfill gas facilities; the remaining ~1% derives from other renewable sources such as wind, hydropower, and solar (U.S. Energy Information Administration 2012; based on 2010 data).

the year 2019. The goals of the RES are to (i) diversify the energy sources supplying electricity consumed in the state, (ii) stabilize long-term energy prices, (iii) enhance environmental quality by reducing air pollutants and carbon dioxide emissions (two factors that adversely affect public health and contribute to global warming), and (iv) create jobs in Rhode Island in the renewable energy sector. The Renewable Energy Standard (RES) stopped short of issuing guidance on renewable energy siting and planning.

Several subsequent policies have picked up where the RES left off. Foremost among these was the 2006 Comprehensive Energy Conservation, Efficiency, and Affordability Act (S903), a suite of legislation that created an institutional framework for renewable energy development in Rhode Island. This Act contained siting considerations scattered throughout its many provisions. Perhaps most importantly, the Act directed the Department of Administration, Division of Planning, Statewide Planning Program to add to the State Guide Plan guidelines for the location of renewable energy resources and facilities in Rhode Island.

Also in 2006, Governor Donald Carcieri set a goal of generating 15% of Rhode Island's electricity from offshore wind power by 2020. During that year, the RIEDC commissioned a study to assess ways in which wind resources in Rhode Island could be used to meet 15% of the state's average electric demand. The study, called RIWINDS, screened and prioritized onshore and offshore areas based on their viability for wind energy installations over 1.5 MW. RIWINDS, which was released in April 2007, concluded that over 95% of utility-scale wind energy opportunities in Rhode Island lie offshore (ATM 2007).

RIWINDS helped characterize the broad resource limitations of wind energy in Rhode Island, but it lacked a stakeholder-informed consideration of constraints on the siting of wind turbines in the state and was targeted at utility-scale facilities, which it ultimately determined to be unfeasible in most of the state's onshore territory. Over the next several years, the Office of Energy Resources, the Statewide Planning Program, and the Rhode Island Economic Development Corporation (RIEDC) considered ways to advance further investigation of land-based siting constraints and energy opportunities around the state.

In the meantime, a parallel comprehensive wind energy siting analysis began to take shape offshore. To identify the most suitable areas off the coast for offshore wind energy development, the Rhode Island Coastal Resources Management Council (CRMC) teamed with the University of Rhode Island in 2008 to initiate development of the Ocean Special Area Management Plan (Ocean SAMP). The Ocean SAMP is a living document that draws on the best available science and robust stakeholder involvement to identify and resolve possible spatial conflicts among multiple ocean uses in the ocean waters off Rhode Island's coast. The Ocean SAMP's analysis of offshore wind resources contemplated potential environmental impacts of wind power facilities and possible conflicts with other ocean uses, giving regulators and developers a head start in prioritizing locations where offshore wind power projects would be feasible, and avoiding locations where development would not be appropriate.

By the time the CRMC approved the Ocean SAMP in 2010, several onshore wind energy facilities had been constructed, and several others had been proposed. Yet the State had not yet performed a comprehensive renewable energy siting analysis or integrated renewable energy into the State Guide Plan as prescribed by the 2006 Comprehensive Energy Conservation, Efficiency, and Affordability Act. In 2010, The Division of Planning initiated work with its own stakeholder advisory committee on the Interim Siting Guidelines, which will be finalized and published after the completion of the RESP. In 2011, the Office of Energy Resources initiated a formal process for renewable energy siting in the state that would help satisfy these lingering needs. This effort, which would ultimately examine hydropower and solar energy in addition to wind power, crystallized in late 2011 as the RESP.

As a result of the successful partnership established between the State and URI during the Ocean SAMP, the Office of Energy Resources asked URI to conduct a similar process for the RESP. The Ocean SAMP did not provide the impetus for the RESP, since the initial events leading to the RESP took place before the Ocean SAMP. However, the Ocean SAMP provided a model which the RESP drew on heavily. This model was based on a two-pronged approach rooted in sound science and extensive stakeholder input. Because the RESP replicated this information-gathering model as much as possible, albeit under a shorter time frame, the RESP and the Ocean SAMP are conceptually congruent, providing a near-seamless treatment of renewable energy planning across the land-sea divide.

Energy in Rhode Island

Rhode Island is interconnected to the wider New England energy production and distribution grid, and both exports and imports electricity to and from other states in the region (ISO New England Inc. 2011a). Electricity generation in Rhode Island, and in New England more generally, is heavily fossil fuel-dependent. In New England, 73% of electricity generated in the region derives from natural gas, oil, and coal (ISO New England Inc. 2011c). In Rhode Island, almost all electricity generation depends on natural gas (ISO New England Inc. 2011a). Gas-fired electrical generating facilities in Rhode Island are located in Burrillville, Providence, Tiverton, and Johnston (Rhode Island Office of Energy Resources 2010); several of these plants have dual-fuel capability that would allow them to generate energy from another fossil fuel source in the event of a natural gas shortage or price spike (ISO New England Inc. 2011c).

Demand for electricity in the region and the nation as a whole is projected to increase in the coming decades (by 8-9% from 2009-2019, and by 29% from 2008-2035, respectively; ISO New England Inc 2009a, U.S. Energy Information Administration 2010). Energy demand in Rhode Island is expected to grow at a rate of 1.2% annually over the next decade, slightly above the 1.1% rate projected for New England (ISO New England Inc. 2011b). There are legal, environmental, and economic reasons that the state has decided that renewable energy should make up part of this expected growth in capacity. These include climate change, ocean acidification, air quality, energy stability, and job creation. Each of these rationales is reviewed below.

Climate change

Scientists around the globe now state that signs of global warming and its consequences – sea level rise, melting of snow and ice, increasing air and ocean temperatures, and increasing precipitation and dryness – are unequivocal (IPCC 2007a). Moreover, the Intergovernmental Panel on Climate Change (IPCC), a consensus-based organization comprised of thousands of the world's climate scientists, is quite certain that most of the observed increase in global average temperatures since the mid-20th century, and its concomitant impacts on ice, snow, sea level, and precipitation, are due to increased greenhouse gas concentrations in the atmosphere stemming from anthropogenic sources, such as fossil fuel combustion (IPCC 2007a). Carbon dioxide concentrations in the atmosphere have risen from pre-industrial levels of 280 parts per million (ppm) to 390.45 ppm in 2011 (NOAA Earth Systems Research Laboratory 2012), representing an increase of 39.4%. IPCC scientists expect that if human-induced greenhouse gas emissions continue unchecked, warming trends and climatic changes during the 21st century will be much greater than those of the 20th century (IPCC 2007a).

Table 1. Effects of climate change in New England and Rhode Island

Observed effect	Location	Time span	Source
Annual average temperatures have risen by 0.83°C (1.5°F).	New England	1900 - early 2000s	Frumhoff *et al*. 2007
Winter temperatures have risen by 2.22°C (4°F).	New England	1970 - 2000	Frumhoff *et al*. 2007
Annual mean temperatures have increased by 10.41°C (18.74°F).	Rhode Island	1905 - 2006	Pilson 2008
Precipitation (rain and snow) have increased by about 32%.	Rhode Island	1905 - 2006	Pilson 2008
Cloudiness is on the rise.	Rhode Island		Nixon *et al*. 2009
Annual average sea surface temperatures have increased by 1.2°C (2.2°F).	Rhode Island coast	1970s - early 2000s	Oviatt 2004
Annual sea surface temperatures have increased by 2.2°C (4°F).	Narragansett Bay	Since the 1960s	Nixon *et al.* 2009
Sea level is rising by an average of 2.58 mm (0.1 in) per year, for a total rise of 25.8 cm (10.2 in) in the last century.	Newport, RI	1930-2008	Boothroyd 2008, cited in CRMC 2010.

The effects of climate change in New England and Rhode Island are increasingly apparent (see Table 1). These effects may have serious consequences for both the environment and economy in Rhode Island. Increased precipitation has potential to cause flooding, property damage, loss of tourism income, increased runoff of pollutants and nutrients into coastal waters, and threats to the safety of infrastructure. Increased temperatures have potential to cause affect recreational opportunities, agriculture, species distributions, and electricity demand. Sea level rise has potential to alter coastal property and infrastructure, and can lead to increased beach erosion and marsh inundation. Species adapted to specific habitats may not be able to adapt to the changing physical characteristics of these habitats, and relationships between species may undergo transformations.

Electricity generation accounts for an increasing percentage of greenhouse gas emissions in the United States, and currently accounts for 40% of man-made carbon dioxide emissions (U.S. EPA 2012a).[2] Based on emissions from power plants, New England's contribution to carbon dioxide emissions per unit energy generated is below the national average,[3] due to the lower carbon dioxide emissions rates of natural gas (U.S. EPA 2012a).[4] However, carbon dioxide is just one of several gases that contribute to the global warming. Methane (CO_4) is pound for pound 25 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year time period (IPCC 2007b). While burning natural gas for energy does not release methane (unless leaks occur), the processes by which natural gas is produced, processed, stored, transmitted, and distributed account for almost one third of human-induced methane emissions in the U.S.[5] While a large segment of the pre-generation handling of natural gas used in New England takes place in other regions, the methane emissions that take place as a result of those processes can be considered an indirect consequence of reliance on natural gas as a predominant power source in New England.

When wind energy is used as a replacement for fossil fuel-based energy, a single 1 MW turbine is estimated to displace approximately 1,800 tons of carbon dioxide per year (AWEA 2009). A solar or hydroelectric project of the same magnitude can be expected to yield a similar result (the actual displacement of greenhouse gases varies as a result of the mix of fuel sources used within a region). IPCC scientists agree that widespread deployment of existing and near-ready renewable energy and energy-saving technologies would make it possible to stabilize

---

[2] Carbon dioxide is not the only gas emitted by electricity generation and other anthropogenic processes that is implicated in causing a greenhouse gas effect, but it represents the largest percentage, at approximately 84% of total greenhouse gas emissions in the U.S. (U.S. EPA 2012b).

[3] New England has an annual carbon dioxide output rate of 827.95 lb/MWh; the U.S. as a whole has an annual carbon dioxide output rate of 1,293.05 lb/MWh (U.S. EPA 2011).

[4] The carbon dioxide output of natural gas is 1,135 lbs/MWh, as compared to coal (2,249 lbs/MWh) or oil (1,672 lbs/MWh) (U.S. EPA 2012c).

[5] Natural gas produces 221.2 $TgCO_2$ equivalents out of a total of methane output in the U.S. 686.3 $TgCO_2$ equivalents (U.S. EPA 2012d).

greenhouse gas concentrations in the atmosphere and avert the worst predicted effects of climate change (IPCC 2007a).

Ocean Acidification

As carbon dioxide continues to accumulate in the atmosphere, much of it is absorbed by ocean waters. The ocean absorbed roughly half of the carbon emitted from human activities between 1800 and 1994 (Sabine *et al.* 2004), and continues to absorb an estimated one-third of current emissions (Feely et al. 2004; Canadell *et al.* 2007; Cooley and Doney 2009). As seawater absorbs carbon dioxide, it becomes more acidic. The IPCC estimates that the average pH of ocean surface water has decreased by 0.1 units since the dawn of the industrial revolution (IPCC 2007a), and predicts that it will increase by another 0.14 to 0.35 units over the 21st century if emissions continue to rise at their present rate (IPCC 2007a).

While the physiological effects of increased acidity on ocean organisms are not yet well documented, ocean acidification is expected to have negative impacts on marine shell-forming organisms and their dependent species (IPCC 2007a). In New England, shelled organisms that may be affected include quahogs, foraminifera, slippershell snails, sea stars, and coral (CRMC 2010). Ocean acidification can also lead to corrosion on vessels and marine infrastructure (CRMC 2010).

Air quality

In addition to producing carbon dioxide and other greenhouse gases, burning of fossil fuels produces nitrous oxides (NO_X), volatile organic compounds, carbon monoxide, sulfur dioxide (SO_2), and particulate matter. Nitrous oxides may contribute to ground level ozone (smog) and acid rain. Ground-level ozone can cause breathing problems, asthma, reduced lung function, and lung diseases (WHO 2011). Acid rain (also called acidic deposition) can harm forests and aquatic ecosystems by changing the pH of the environment, and can damage surfaces such as car exteriors (U.S. EPA 2012c). Sulfur dioxide may contribute to acid rain and can cause respiratory problems such as bronchoconstriction and increased asthma symptoms (U.S. EPA 2012d). Particulate matter, which consists of a mixture of solid and liquid particles suspended in the air, has is thought to increase the chances of incurring respiratory disease, cardiovascular disease, and lung cancer (WHO 2011). Natural gas, the primary fuel used for electricity generation in Rhode Island, releases lower quantities of harmful air pollutants than coal and oil.[6] However, this does not mean that the effects are negligible.

When wind energy is used as a replacement for fossil fuel-based energy, a single 1 MW turbine displaces an estimated 9 tons of sulfur dioxide and 4 tons of nitrogen oxide each year (AWEA 2009). A solar or hydroelectric project of the same magnitude can be expected to yield

[6] Natural gas produces only 0.1 lbs/MWh of sulfur dioxide (compared to 13 lbs/MWh for coal and 12 lbs/MWh for oil), and 1.7 lbs/MWh of nitrogen oxides (compared to 6 lbs/MWh for coal and 4 lbs/MWh for oil; U.S. EPA 2012b).

a similar result (the actual displacement of air pollutants varies as a result of the mix of fuel sources in a region).

Energy stability

Natural gas is not an energy resource indigenous to New England; it is imported to the region through natural gas pipelines from other states in the Northeast, Texas, Louisiana, the Trans-Canada pipeline passing through New York and Vermont, and through the offshore LNG receiving facilities Northeast Gateway Deepwater Port and Neptune LNG LLC, located off the coast of Massachusetts (U.S. Energy Information Administration 2009; U.S. Department of Energy 2004; Rhode Island Office of Statewide Planning 2002; Excelerate 2010). If long-distance shipping of gas were ever to become impractical or expensive, Rhode Island would be cut off from this critical supply.

Price stability

Rhode Island's almost exclusive dependence on natural gas exposes it to fluctuations in the price of energy. The U.S. Department of Energy (2004) recognized the region's need for increased energy "to alleviate New England's volatile energy market and reduce its over-reliance on natural gas….thereby increasing electric reliability and lowering energy costs by utilizing local resources in the generation of electricity (U.S. Department of Energy 2004:1)." Indigenous energy sources like wind, solar, and hydropower can be produced within Rhode Island's borders, providing a greater guarantee of availability in the face of uncertainty.

Economic development and job creation

As a new industry, renewable energy has the potential to create new jobs. Moreover, unlike coal mining or oil drilling, renewable energy generation can take place in Rhode Island, keeping more jobs in the region where the energy is consumed.

According to the US Department of Energy, wind energy development creates thousands of long-term, high-paying jobs in fields such as wind turbine component manufacturing, construction and installation, maintenance and operations, legal and marketing services, transportation and logistical services, and more (U.S. DOE 2011). In 2010, an estimated 75,000 people were employed in the wind industry across the U.S. (U.S. DOE 2012), and employment in the wind turbine manufacturing industry along has increased rapidly in the last several years. The American Wind Energy Association (AWEA) reports that in 2008 alone, the industry grew by 35,000 new workers (AWEA 2010).

Likewise, solar energy employs thousands of people in the manufacturing, sales and distribution, and installation of solar photovoltaic systems. The solar energy industry employed 100,237 people in 2012, up from 93,502 the year before (The Solar Foundation 2011). The number of solar jobs in the U.S. is expected to increase by 24% in 2012 (The Solar Foundation 2011).

Potential drawbacks to renewable energy

While renewable energy is of interest to many stakeholders because of the benefits cited above, it should be noted that no energy source is entirely free of consequences. While renewable sources such as wind, solar, and hydropower may avoid many of the downsides associated with the burning of fossil fuels, they may nonetheless have negative impacts that communities should consider. Previous experience around the world suggests that renewable energy facilities, when not sited appropriately, can on occasion have deleterious effects on local quality of life and wildlife populations. In contrast to conventional energy sources, which tend to have negative externalities that are spread over large regions (e.g., air pollution) or the entire globe (e.g., climate change), the externalities of renewable energy sources may be highly localized (e.g., acoustic impacts of wind turbines), leading affected residents to feel that they are disproportionately affected.

For these reasons, the RESP does not take a one-sided stance in favor of renewable energy promotion. Instead, the RESP adopts a neutral stance and strives to shed light on both the opportunities and negative consequences associated with development of this new industry in Rhode Island, so that municipalities in the state can make informed decisions tailored to their own unique local circumstances and preferences. Above all, the intent of the RESP is to promote careful siting and planning as tools to help municipalities attain the benefits of renewable energy without causing inadvertent impacts on local residents and wildlife.

2. Objectives of the RESP

URI's Coastal Resources Center (CRC)/R.I. Sea Grant and the URI Outreach Center formally initiated the RESP process in August 2011 and concluded it in December 2012. The goal of the RESP was not to promote renewable energy or to determine the best spots in the state to site renewable energy projects. Rather, in light of Rhode Island's Renewable Energy Standard mandate to obtain 16% of the state's electricity from renewable sources by 2019, and the growing interest in renewable energy around the state as a route to economic development and environmental protection, the RESP set out to collect and synthesize information that would serve local decision makers and stakeholders as they make siting and permitting decisions in their own communities.

The focus of the RESP was limited to potential onshore wind energy projects between 100 kW and 1.5 MW, low-head hydroelectric power on existing dams in the state, and solar power facilities of at least 1 MW located on closed landfills. These categories were selected because they represented the most common types of onshore renewable energy projects under consideration at the time by municipalities, state agencies, and other private and public entities with an interest in renewable energy. Residential wind energy projects (typically less than 100 kW) may also have potential to help satisfy renewable energy goals, and are actively being pursued around the state; however, since the impacts of residential wind projects on the environment and surrounding community are generally less significant, they do not call for evaluation through an extensive scientific and stakeholder process like that represented by the RESP.

As part of the RESP process, the CRC/R.I. Sea Grant and URI Outreach Center distributed funds among research teams at URI to gather, interpret, and analyze existing and original data on renewable energy potential and impacts in Rhode Island and elsewhere. These projects included the following:

- Wind resource assessment and facility siting methodology (Dr. Annette Grilli and Malcolm Spaulding, URI Graduate School of Oceanography)
- Acquisition and analysis of wind profile data at selected sites (Dr. John Merrill, URI Graduate School of Oceanography)
- Development of a model to predict acoustic and flicker fields associated with wind turbine operation (Dr. Gopu Potty and Dr. Jim Miller, URI Graduate School of Oceanography)
- Analysis of potential electromagnetic interference with communication systems from wind turbines (Dr. Gopu Potty and Dr. Jim Miller, URI Graduate School of Oceanography)
- Assessment of regulatory and scientific information on the ecology of birds and bats using terrestrial areas of Rhode Island (Dr. Peter Paton, URI Department of Natural Resources)
- Provision of geographic information systems support and construction of a web-based decision support tool for renewable energy siting (Chris Damon, URI Environmental Data Center)
- Assessment of the potential for landfill solar power in Rhode Island (URI Outreach Center)
- Assessment of the potential for hydropower facilities at existing dams (URI Outreach Center)
- Development of the RIEnergy.org website (URI Outreach Center)
- Assessment of the financial feasibility and economic impacts of renewable energy projects (Dr. James Opaluch, URI Department of Environmental and Natural Resource Economics)

The results of these projects are available in their entirety in Volume 2 (Technical Reports) of the present report; they also form much of the basis for Volume 1 (Summary Document).

In addition, the CRC/R.I. Sea Grant and URI Outreach Center conducted an integrated stakeholder outreach and engagement process to incorporate public knowledge and preferences for siting and permitting of renewable energy in the state. As part of this effort, the RESP hosted monthly general stakeholder meetings, field trips to current renewable energy sites, a traveling library lectures series, two targeted hydropower stakeholder workshops, a Renewable Energy Day, a series of Municipal Working Group meetings, and a series of Wind Energy Siting Working Group meetings. The RESP stakeholder process helped inform both the RESP research and production of the RESP findings document, and is described in detail in Chapter 6 of this volume.

3. A User's Guide to RESP Products

The intended end users of the RESP products are renewable energy stakeholders and decision makers in Rhode Island. Municipal decision makers are anticipated to be the primary users of the RESP, but other stakeholders and decision makers, including the public, state officials, the advocacy community, and energy developers, are also expected to make use of RESP findings and tools as they evaluate renewable energy options in areas of interest to them.

The RESP findings are not intended to supersede any site-specific analyses that would be required before project development or construction. Potential developers are responsible for conducting necessary studies of a proposed facility site, including assessments of specific impacts that the proposed project may have on the surrounding environment and community. However, RESP findings may be used by developers and decision makers to make informed preliminary judgments about an area's development potential or to make rough comparisons among various seemingly viable development sites. Moreover, the RESP findings represent a publicly accessible, centralized collection of information that will enable community members and others to formulate educated opinions about renewable energy options in their communities. It is hoped that this information will improve development proposals, increase transparency with regard to potential impacts of proposed developments, and provide for a collaborative exchange of ideas and information among developers, decision-makers, and community members when deciding whether and where to construct renewable energy facilities in a community.

The RESP presents its findings in two forms. The first is this report: a document containing accounts from other places, local stakeholder insight, and original research by URI scientists on predicted opportunities and constraints associated with development of wind, solar, and hydropower in Rhode Island. The second is a Rhode Island-specific website housing energy data, resource and siting-decision support mapping tools, and information for citizens, businesses, and government officials. This energy information clearinghouse is called RI Energy.org. Both the report and the website are decision-making tools designed to facilitate the appropriate siting of renewable energy facilities in Rhode Island and to identify possible impacts and mitigation requirements associated with future projects.

Volume 1 of the RESP report brings together literature collected from other places, original research conducted in Rhode Island, and stakeholder input gathered during the RESP process, to explore renewable energy production potential and identify environmental, economic, social, and legal issues potentially associated with the growth of renewable energy in the state. Chapter 1, Wind Energy, discusses the distribution of wind resources across Rhode Island and describes several possible impacts of concern related to wind energy development. These include safety concerns, acoustic impacts, shadow flicker, impacts on birds and bats, visual/aesthetic impacts, impacts on cultural and historic resources, and impacts on property values. The chapter then presents a series of maps developed by the RESP to aid in siting of wind turbines in Rhode Island. Chapter 2, Landfill Solar Energy, discusses opportunities and constraints facing deployment of utility-scale photovoltaic solar systems on closed landfills in Rhode Island. It includes a screening methodology developed by the RESP to identify possible landfill sites suitable for solar development. Chapter 3, Hydropower, summarizes the RESP assessment of power potential at existing dams in Rhode Island and discusses possible hydropower siting constraints, including environmental, cultural, historical, public safety, and regulatory considerations. Chapters 1-3 conclude with descriptions of legal and regulatory factors relevant to energy siting and permitting at both the federal and Rhode Island levels for each of these three forms of renewable energy, respectively.

Chapters 4-5 of Volume 1 complement energy source-specific information with additional analysis applicable to all three types of renewable energy reviewed in Chapters 1-3. Chapter 4, RI Energy.org, describes the design, development, and contents of the online decision support and informational tools available at RI Energy.org. Lastly, Chapter 5, Stakeholder Process and Public Engagement, explains the ways in which the RESP drew on the expertise and insights of key constituencies and the general public to create a set of tools fully tailored to Rhode Island's unique social and environmental context.

Volume 2 of the RESP report contains a collection of documents offering greater detail on the information presented in Volume 1. Several of these documents describe the methods and results of the research carried out by URI scientists in support of the RESP. Since many RESP users will refer primarily to the summary chapters collected in Volume 1, rather than read the more detailed analyses presented in Volume 2, the highlights of RESP research are synthesized in the chapters of Volume 1. Volume 2 also contains several documents pertaining to renewable energy policy and regulations in Rhode Island. These include detailed descriptions of state and federal regulations pertaining to the siting of wind, solar, and hydropower, as well as a summary of legislative actions that took place around the time of the RESP supporting renewable energy development in Rhode Island.

RI Energy.org is Rhode Island's first centralized online clearinghouse for state energy information and analytics. In addition to presenting background information on energy production and usage in Rhode Island, the website includes a collection of user-friendly online mapping tools that RESP users may draw upon to (1) visualize the solar, wind, and hydropower production potential at different locations around the state and (2) evaluate possible impacts of solar, wind, and hydropower production on the human and natural environment at different sites. The RESP online map viewer tools incorporate original RESP data, data collected from other sources, and models developed by URI scientists as part of their RESP research. By using the

RESP online siting tools, local decision makers and the public can interpret data on renewable energy resources and predict potential impacts. RESP online siting tools are described in detail in Chapter 4 of this volume.

4. References

ATM. 2007. RI Winds Summary Report, Applied Technology and Management for RI Office of Energy Resources, Providence, RI. Available online at: http://www.energy.ri.gov/documents/renewable/RIWINDS_RANKING.pdf

AWEA (American Wind Energy Association). 2009. Wind Energy Basics. Washington, D.C. Available online at: http://www.awea.org/newstoom/pdf/Wind_Energy_Basics.pdf. Last accessed May 6. 2010.

AWEA (American Wind Energy Association). 2010. U.S. Wind Industry Annual Market Report 2010. Available online at: http://www.awea.org. Last accessed May 23, 2012.

Canadell, J.G., LeQuéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A. and Marland, G. 2007. Contributions to accelerating atmospheric CO2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences* 104:18866-18870.

Cooley, S.R. and Doney, S.C. 2009. Anticipating Ocean Acidification's Economic Consequences for Commercial Fisheries. *Environmental Research Letters* 4: 02407-02414.

CRMC (Coastal Resources Management Center). 2010. Rhode Island Ocean Special Area Management Plan. Available online at: http://seagrant.gso.uri.edu/oceansamp/documents.html. Last accessed May 23, 2012.

Excelerate. 2010. Northeast Gateway Deepwater Port. Available online at: www.excelerate.com. Last accessed June 30, 2010.

Feely, R.A., Sabine, C.L., Lee, K., Berelson, W., Kleypas, J., Fabry, V.J. and Millero, F.J. 2004. Impact of anthropogenic CO2 on the CaCO3 system in the ocean. *Science* 305:362-366.

Frumhoff, P., McCarthy, J., Melillo, J., Moser, S. andWuebbles, D. 2007. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions.* Synthesis report of the Northeast Climate Impacts Assessment (NECIA). 160 pp. Union of Concerned Scientists (UCS), Cambridge, MA.

IPCC (Intergovernmental Panel on Climate Change). 2007a. The AR4 Synthesis Report. Available online at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html Last accessed March 6, 2012.

IPCC (Intergovernmental Panel on Climate Change). 2007b. Working Group I: The Physical Science Basis. Available online at: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html Last accessed March 6, 2012.

ISO New England Inc (Independent System Operation New England). 2009. ISO New England 2009 Regional System Plan. ISO New England Inc., October 15, 2009. Available online at: www.iso-ne.com. Last accessed January 8, 2010.

ISO New England Inc. 2011a. 2011 Regional System Plan. Available online from: http://www.iso-ne.com/nwsiss/grid_mkts/key_facts/ri_12-2011_profile.pdf

ISO New England Inc. 2011b. New England Regional System Plan (RSP11) System Overview. Available online from: http://www.isone.com/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2011/may232011/system_overview.pdf. Last accessed March 5, 2012.

ISO New England Inc. 2011c. Rhode Island 2011-2012 State Profile. Available online at: http://www.iso-ne.com/nwsiss/grid_mkts/key_facts/ri_12-2011_profile.pdf. Last accessed March 5, 2012.

Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki B.L. and Henry, K.M. 2009. The impact of changing climate on phenology, productivity, and benthic-pelagic coupling in Narragansett Bay. *Estuarine, Coastal and Shelf Science* 18:1-18.

NOAA (National Oceanic and Atmospheric Administration) Earth Systems Research Laboratory. 2012. Trends in Atmospheric Carbon Dioxide. Available online at: http://www.esrl.noaa.gov/gmd/ccgg/trends/index.html#global. Last accessed March 5, 2012.

Oviatt, C. 2004. The changing ecology of temperate coastal waters during a warming trend. *Estuaries* 27:895-904.

Pilson, M.E.Q. 2008. Narragansett Bay amidst a globally changing climate. In: *Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century*, pp. 35-46. Desbonnet, A., and Costa-Pierce, B.A., (eds.), Springer Publishing, New York.

Rhode Island Office of Energy Resources. 2010. Rhode Island State Energy Plan. Available online at: http://stac.ri.gov/files/0000/0148/RI_State_Energy_Plan_Working_Draft-1.pdf. Last accessed March 10, 2010.

Rhode Island Office of Statewide Planning. 2002. Rhode Island Energy Plan 2002. Report # 103 Element 781, August 2002. Available online at: www.planning.ri.gov/ed/rienp2002.htm. Last accessed January 8, 2010.

Sabine, C.S., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C.S., Wallace, D.W.R., Tillbrook, B., Millero, F.J., Peng, T-H., Kozyr, A., Ono, T. and Rios, A.F. 2004. The oceanic sink for anthropogenic CO2. *Science* 305:367-371.

The Solar Foundation. 2011. National Solar Jobs Census 2011. Available online at: http://thesolarfoundation.org/research/national-solar-jobs-census-2011 Last accessed March 7, 2012.

U.S. Department of Energy. 2004. White Paper: Natural Gas in the New England Region: Implications for Offshore Wind Generation and Fuel Diversity. Available online at: http://www.nae.usace.army.mil/projects/ma/ccwf/app2a.pdf. Last accessed October 25, 2012.

U.S. DOE (United States Department of Energy). 2011. Wind Energy Benefits. DOE/GO/102011-3226.

U.S. DOE (United States Department of Energy). 2012. Top Ten Things You Didn't Know About Wind. Available online at: http://energy.gov/articles/top-10-things-you-didnt-know-about-wind. Last accessed October 25, 2012.

U.S. Energy Information Administration. 2009. Expansion of the U.S. Natural Gas Pipeline Network: Additions in 2008 and Projects through 2011. Available online at: http://www.eai.doe.gov. Last accessed April 12, 2010.

U.S. Energy Information Administration. 2010. Annual Energy Outlook 2010, Early Release Overview. Report No. DOE/EIA-0383.Washington, DC: EIA. 2009. Available online at: http://www.eia.doe.gov. Last accessed March 14, 2010.

U.S. Energy Information Administration. 2012. State Renewable Electricity Profiles 2010. Available online at: http://205.254.135.7/renewable/state/pdf/srp2010.pdf. Last accessed June 12, 2012.

U.S. EPA (Environmental Protection Agency) 2012a. Air Emissions. Available online at: http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html Last accessed March 6, 2012.

U.S. EPA (Environmental Protection Agency) 2012b. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Available online from: http://epa.gov/climatechange/emissions/usinventoryreport.html Last accessed March 6, 2012.

U.S EPA (Environmental Protection Agency) 2012c. How does electricity affect the environment? Available online at: http://www.epa.gov/cleanenergy/energy-and-you/affect/index.html. Last accessed October 25, 2012.

U.S. EPA (Environmental Protection Agency) 2012d. Sources and Emissions. Available online at: http://www.epa.gov/outreach/sources.html Last accessed March 6, 2010.

WHO (World Health Organization). 2011. Air Quality and Health. Fact Sheet No. 313. Available online at: http://www.who.int/mediacentre/factsheets/fs313/en/ Last accessed March 6, 2012.

RENEWABLE ENERGY SITING PARTNERSHIP

CHAPTER 1. WIND ENERGY

Table of Contents

List of Figures

List of Tables

1. Introduction

Siting a wind energy project is a careful balancing act involving a careful consideration of both the available wind resource and the potential impacts that the project may pose to the surrounding area. The RESP provides several tools to enable local decision makers and the public to perform such analyses in a way that responds to their unique preferences and circumstances. The purpose of this chapter is to provide a summary of the best available science regarding wind resources in Rhode Island and to highlight relevant siting considerations that municipalities may wish to consider when reviewing or siting a wind energy project. Many of these siting issues were identified in collaboration with the public through the RESP's extensive stakeholder engagement process. Chapter 6 of this report describes the greater detail the role of stakeholder feedback in guiding the RESP process.

The purpose of this chapter is not to site wind energy projects in Rhode Island, but to describe what is known about the wind resources in the state and provide key information that should be taken into account to help others when siting a project or reviewing an application. Because every potential project site is different, site-specific investigations will be necessary to accurately gauge the impact and economic viability of a particular project.

The focus of this chapter is primarily on wind energy facilities that range in size between 100 kilowatts (kW) to 1.5 megawatts (MW). This size range was selected because it encompasses both small-scale commercial facilities and municipal-scale projects. These projects are significant because they are the types of projects currently under review or in planning stages in local communities in Rhode Island. This chapter does not discuss residential-scale wind projects for personal use, which traditionally are less than 100kW. While residential-scale development may also be of interest in Rhode Island, it is beyond the scope of the RESP project. Nor does this chapter address large-scale commercial wind farms comprised of many wind turbines, as these are less likely to be proposed in Rhode Island.

This chapter begins with a discussion of what is currently known about available wind resources in Rhode Island based on existing data collected in the state. It then discusses potential effects of wind energy, including safety considerations, shadow flicker, electromagnetic or signal interference, effects on birds and bats, impacts to cultural or historic resources, visual impacts, and impacts on property values. Lastly, the chapter presents an overview of federal and state laws and regulations relevant to wind energy, with the purpose of describing the overarching legal context governing wind energy development in the state.

2. Wind Resource Assessment

Section Summary

- Rhode Island wind speeds reflect the fact that the state is relatively flat, and unable to take advantage of the increases in wind speed associated with high elevations.
- Much of the inland portion of Rhode Island is forested, contributing to a high degree of surface roughness that slows wind speeds in that portion of the state.
- The highest wind speeds in Rhode Island tend to be close to the coast, due to this area's proximity to the flat expanse of the ocean.
- The U.S. Department of Energy estimates that wind energy production currently requires wind speeds greater than 7 m/sec (16mph) at 80m (262 ft). According to previous modeling by AWS TrueWind, Rhode Island has an average wind speed of 5.5-6.0 meters/sec (12-13mph) at 80m (262ft).
- Coastal regions of the state have higher wind speeds, measuring an average of 6.5-7.5 meters/sec (15-17mph) at 80m (262ft). Block Island has the highest wind speeds in the state, at 8-9 meters/sec (18-20mph) at 80m (262ft).
- There is more seasonal variation in wind speeds closer to the shore, but greater daily variation in wind speeds as one moves further inland.
- Available wind resources can be further refined by considering the technical constraints on energy production, such as the efficiency of the turbine, and the practical constraints, which are reviewed in Section 3.

Availability of commercially significant wind resources in Rhode Island is a prerequisite for considering wind energy development within the state. RESP research confirmed the findings of prior studies that Rhode Island possesses some areas with commercially viable wind resources at current technological levels. As technology improves, the harvestable wind resources in the state may increase.

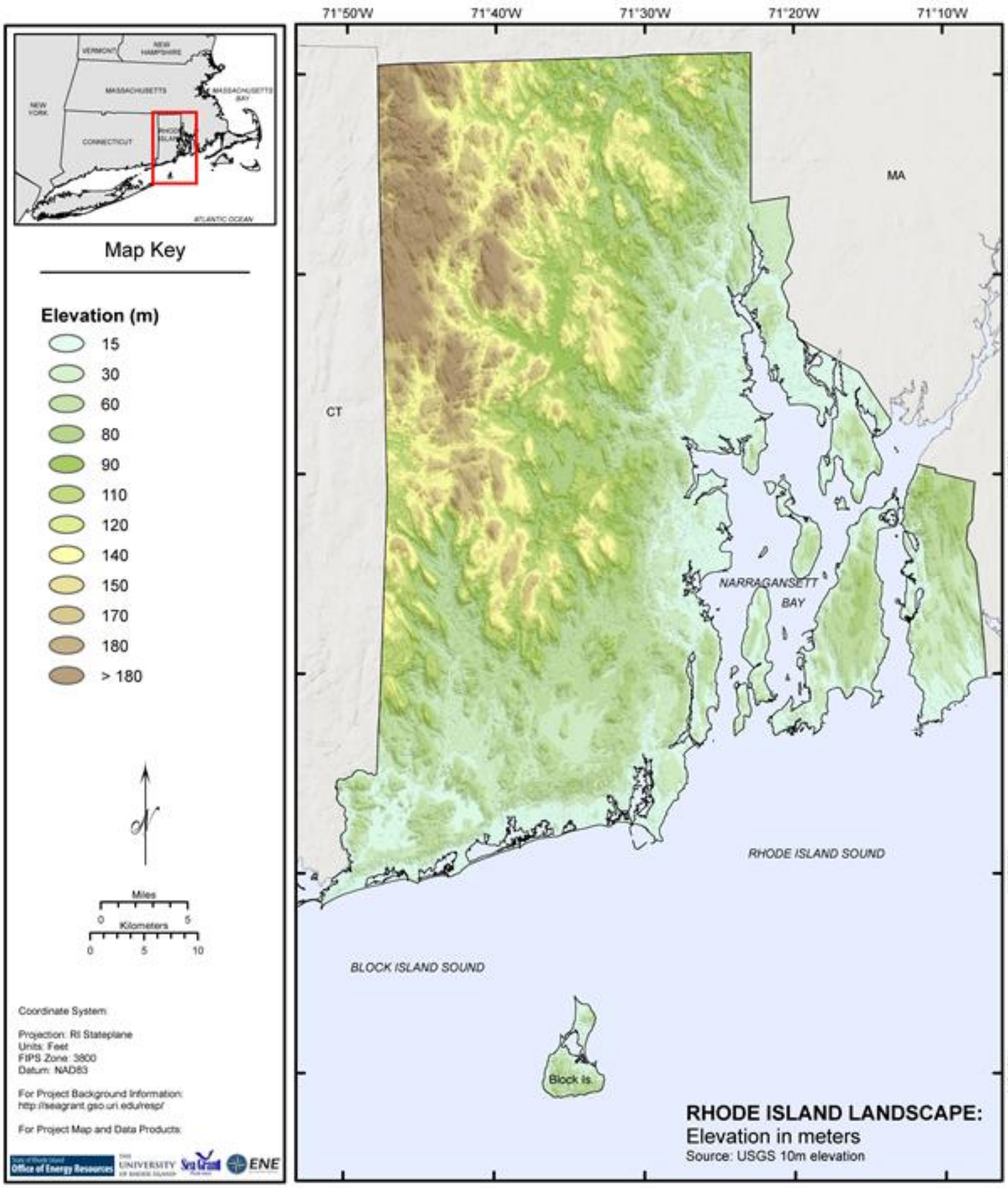
Land-based wind resources were first examined across the state by the RI Winds study (ATM, 2007). That study evaluated wind resources across the entire state (including offshore waters) to identify the most viable areas for wind energy development. Unlike the RESP, the RI Winds evaluated wind resources exclusively from the perspective of utility-scale turbines (1.5MW or larger). The results of that study demonstrated that the greatest potential for utility-scale development exists offshore. According to the study, land-based wind energy potential at scales greater than 1.5MW is limited because, at 80 m, only 2.6% of Rhode Island's land mass has mean annual wind speeds over 7 m/s. The RESP expanded upon the RIWINDS study by examining in greater detail the wind resources of the state and considering the potential for smaller wind energy projects ranging between 100kW-1.5MW.

2.1 Average Wind Speeds across Rhode Island

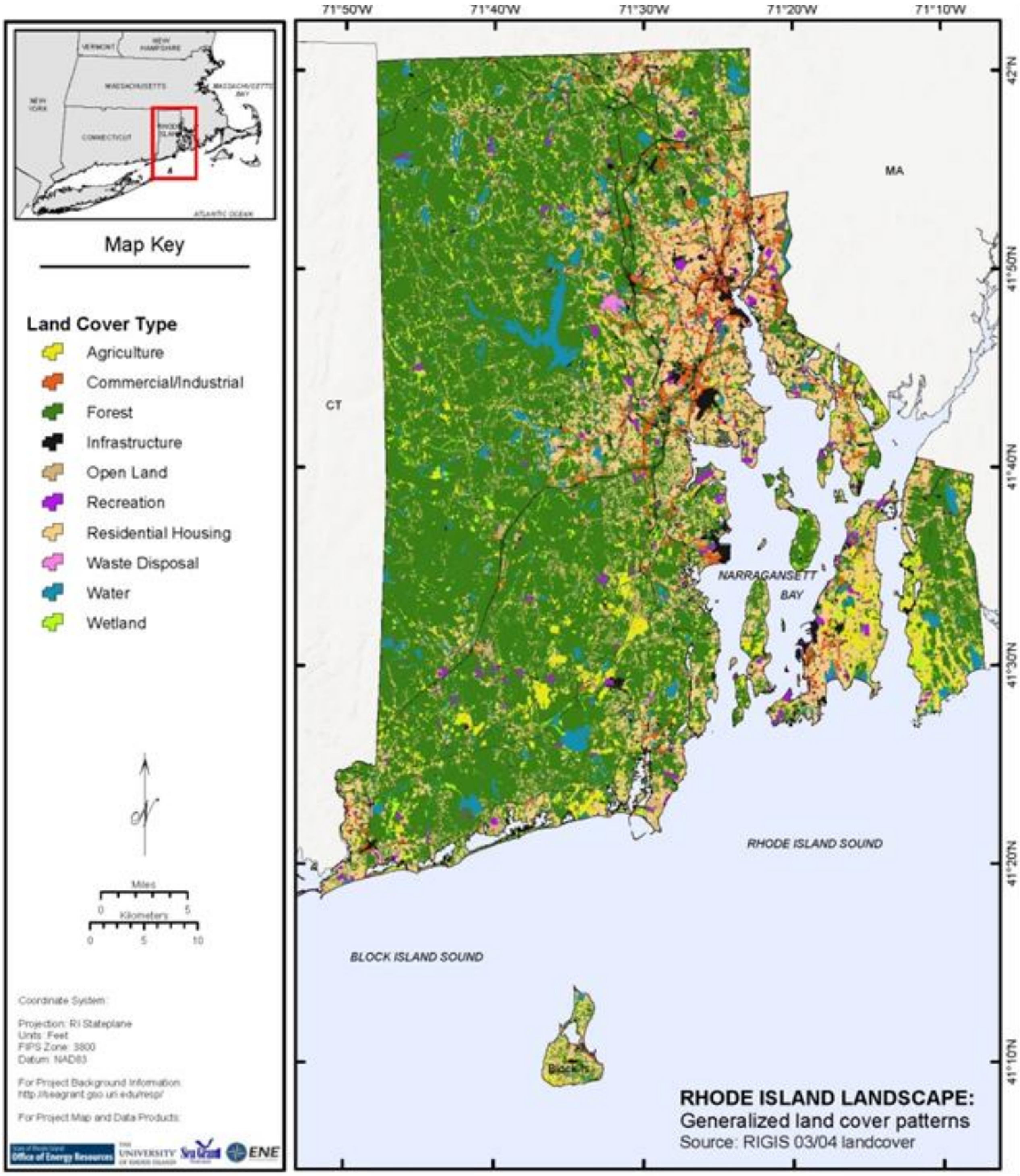
Wind resources can be compared horizontally across a landscape or vertically across a range of elevations. Understanding how wind speeds vary across a landscape is important when selecting a potential project site, while understanding vertical variation in wind resources is useful for understanding wind speeds at the height at which it would be harvested by a particular turbine. Research conducted for the RESP examined wind resources in both dimensions, comparing wind resources across Rhode Island and assessing vertical variation in wind resources at selected sites (see Grilli et al., 2012 and Merrill and Knorr, 2012 in Volume II of this report).

Wind speed and direction is determined by macro-scale atmospheric patterns influenced by temperature, pressure, and humidity. On smaller scales, it is shaped by topography and land cover, which influence the behavior of the wind near the land surface. For example, when wind flows over a topographic feature such as a mountain ridge, wind speeds are accelerated. In addition, wind speeds are greater at higher elevations. In contrast, areas with rough land cover, such as forests, tend to slow the wind.

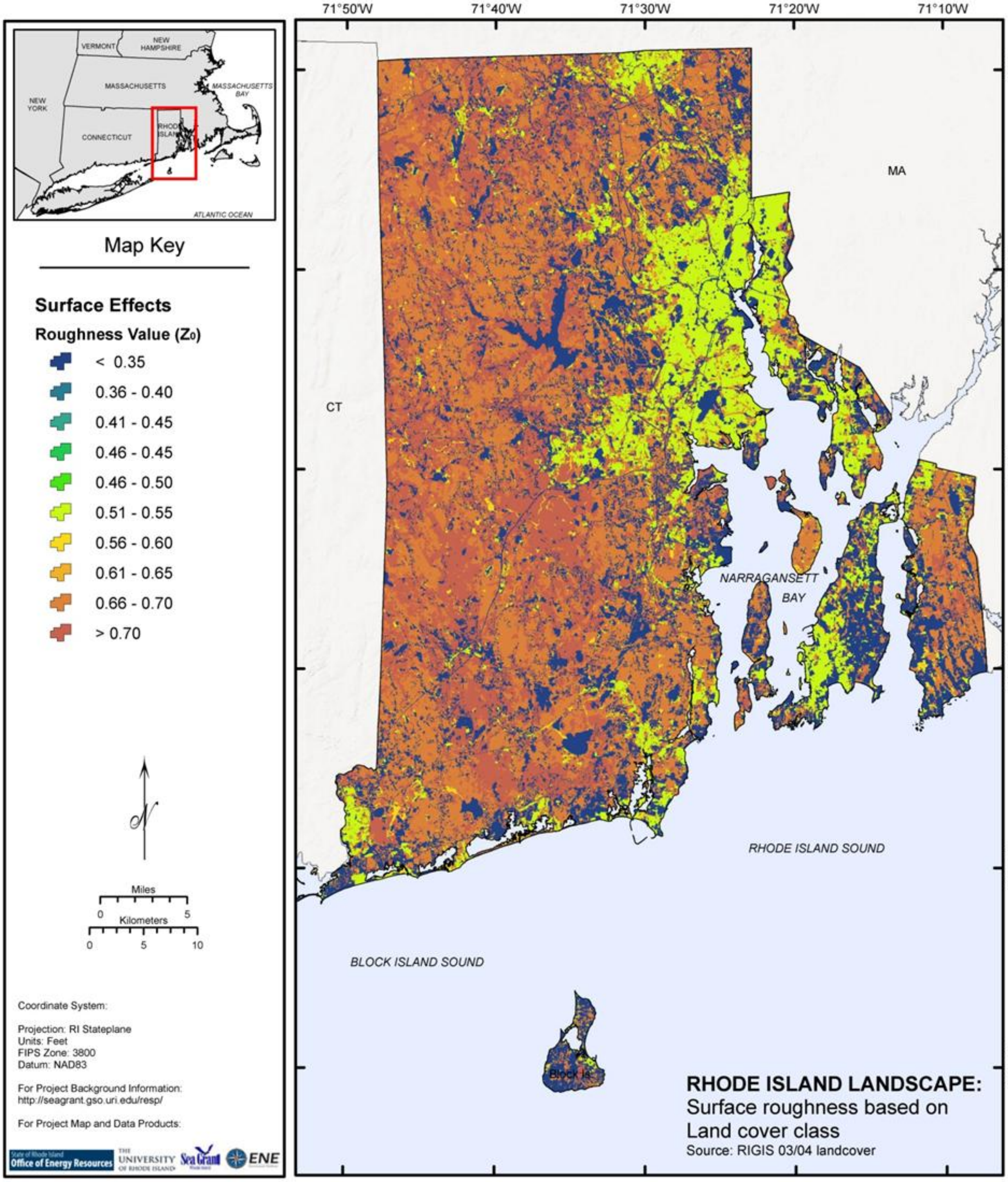
Rhode Island's topography and land cover offer a good starting point for predicting wind speeds across the state. The highest elevations are present in the northwestern part of the state (see Ch. 1 Figure 1), however these are also areas that are densely forested (see Ch. 1 Figure 2) and thus have higher surface roughness (see Ch. 1 Figure 3), which lowers wind speed in these areas. Moreover, despite the presence of hilly areas in the northwestern part of the state, Rhode Island is relatively flat, with the highest point in the state only reaching just over 812 feet (247m) in the Town of Foster. As a result, Rhode Island's wind resources are lessened by the fact that the state lacks areas where high elevation and low surface roughness overlap.



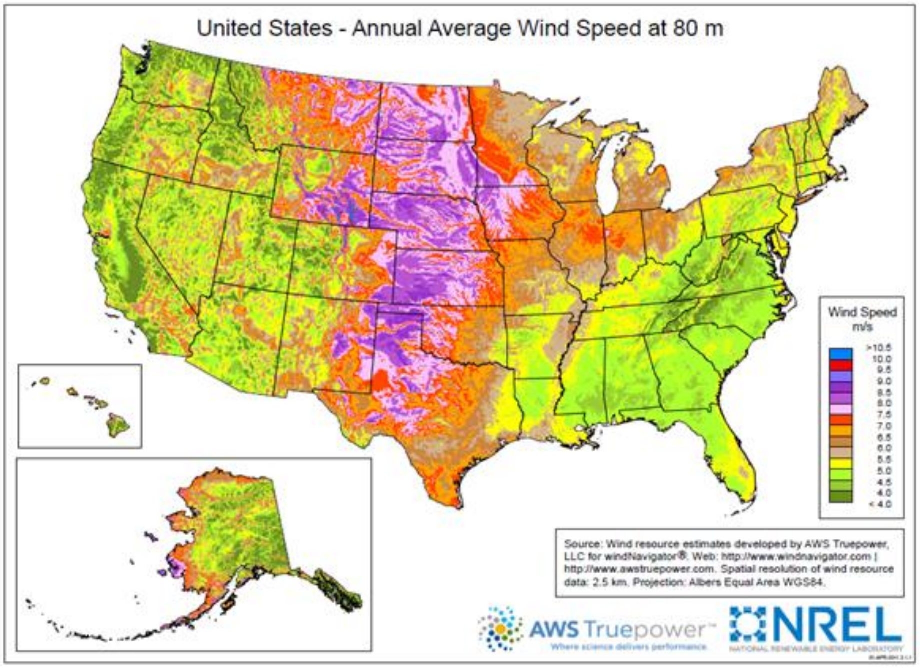
Ch. 1 Figure 1. Topography in Rhode Island.

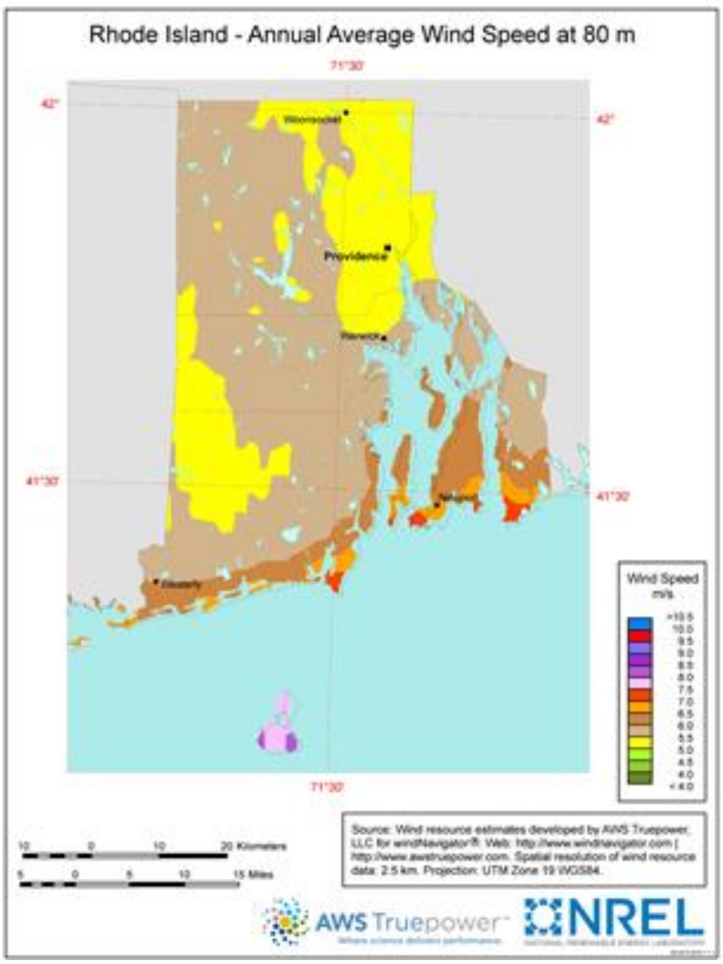


Ch. 1 Figure 2. Generalized Land Cover Patterns Across Rhode Island.



Ch. 1 Figure 3. Surface Roughness Across Rhode Island Based on Land Cover.





Ch. 1 Figure 4. Annual average wind speeds at 80 m (262 ft) in elevation. (Figure based on modeled wind produced by AWS Truepower, formerly named AWS TrueWind.)

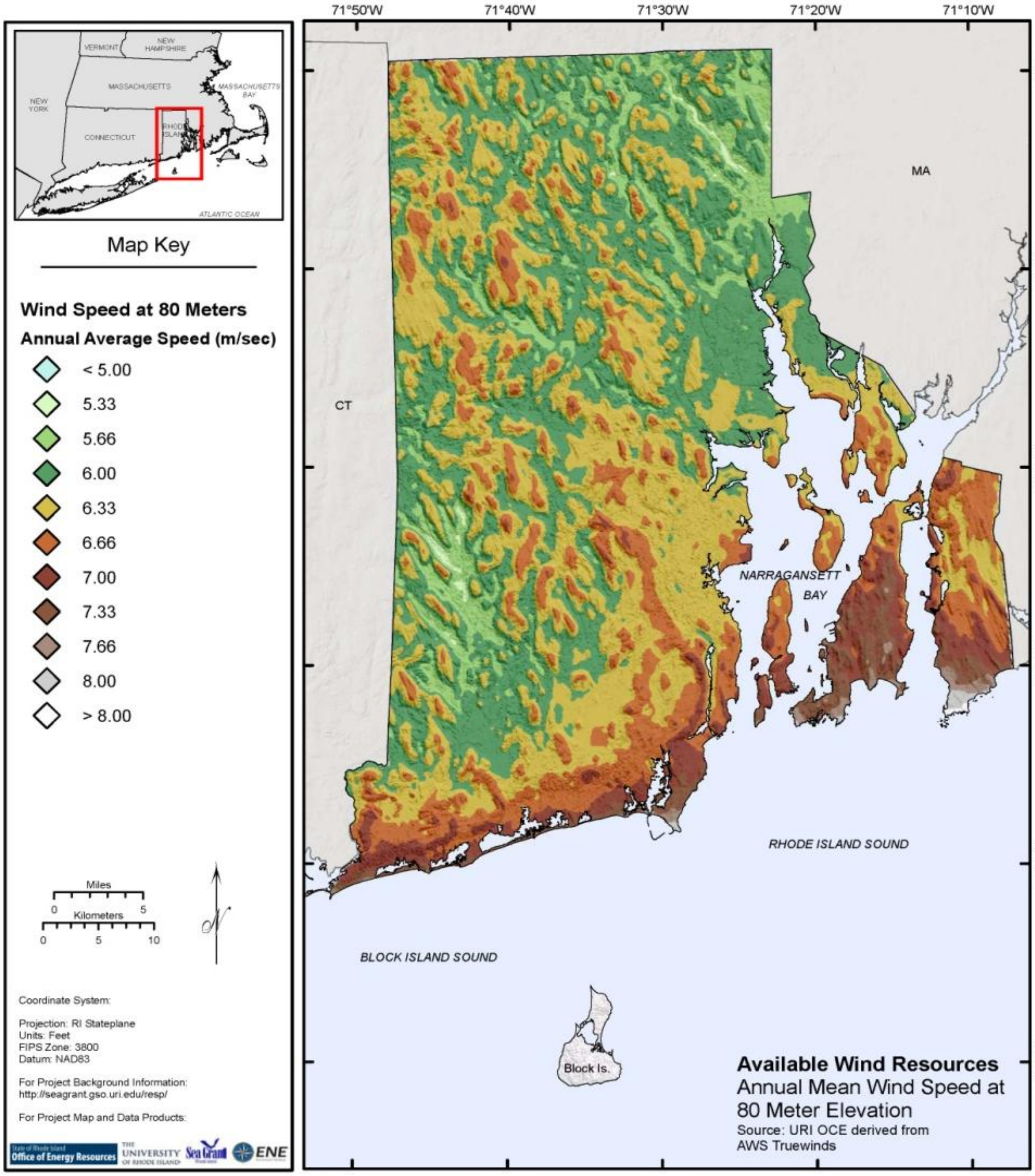
Wind resource maps are based on models that generate estimates of wind speed across a map grid at a given elevation taking into account topography, land cover and surface roughness. The RESP assessed wind resources by drawing on three-dimensional modeled wind data (AWS Truewind, 2007) and on observations of wind profile data at selected sites (Grilli et al. 2012). Wind resource models are not a substitute for observational data; their utility lies in that they can be used to extrapolate existing data across much larger areas, such as an entire state, as well as vertically and over time.

2.2 Modeled wind speeds across Rhode Island

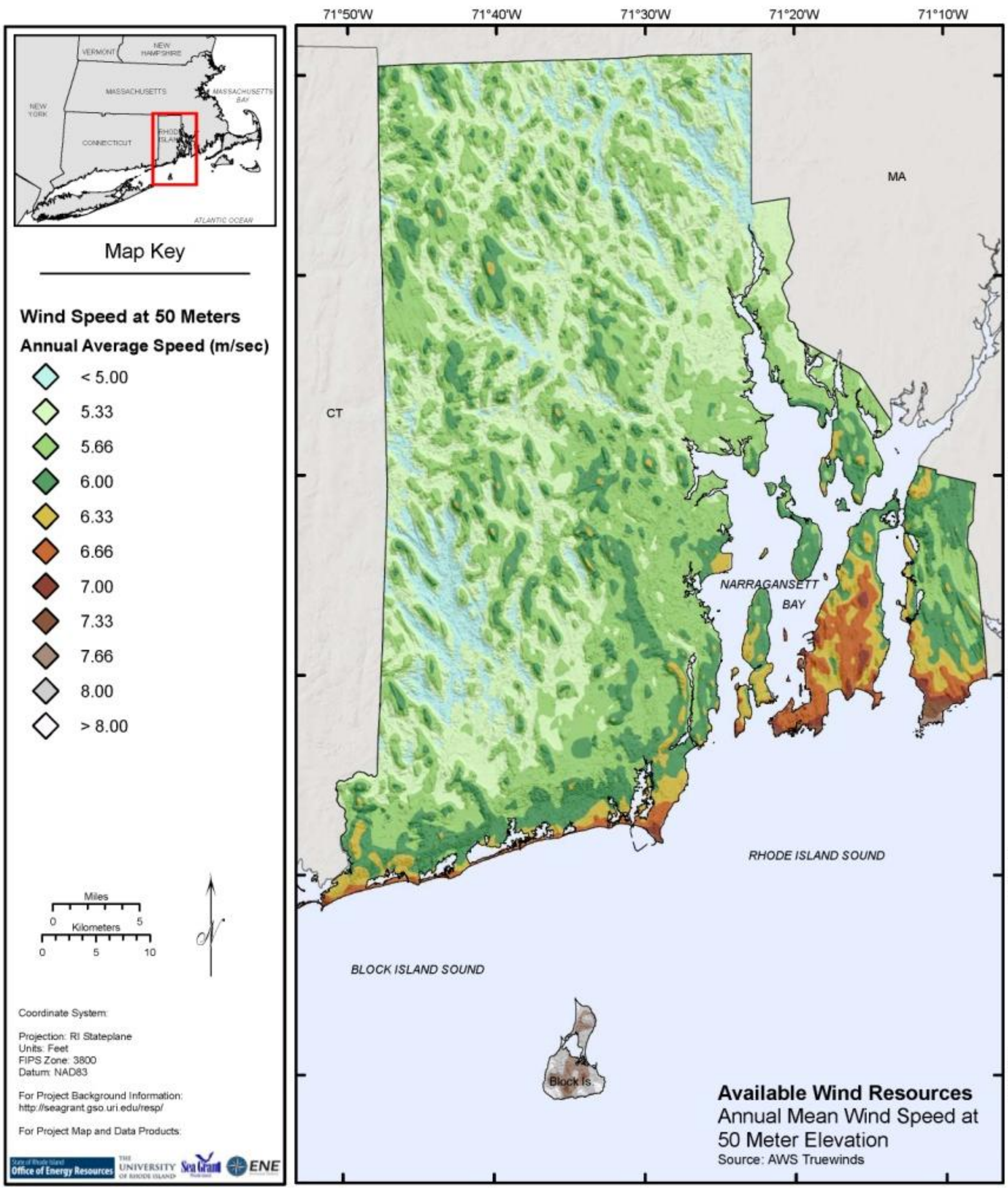
Wind speeds at various heights have been modeled by AWS TrueWind for the entire New England region, using a mesoscale meteorological model and wind flow simulation model with a resolution of 200m x 200m (656ft x 656ft). The AWS Truewind MesoMap was validated with weather observations from surface stations, instrumented balloons, satellites, aircraft, and other instruments. These models incorporate weather data, sea-surface temperatures, land cover, topography, and other geophysical data also drive the simulations. Ch. 1 Figure 4 is the AWS TrueWind map of annual average wind speeds at a height of 80 meters (262ft) for the entire United States.

The AWS Truewind modeled data suggests that overall, the fastest winds within the state are located along the southern coastline (see Ch. 1 Figure 5). For example, at 80m (262ft), the majority of the state has average annual wind speeds ranging from 5.5-6.0m/sec (12-13mph), while coastal regions having averages of 6.5-7.5m/sec (15-17mph), and Block Island has the highest average annual wind speeds, equaling 8-9m/sec (18-20mph; see Ch. 1 Figure 5). Plentiful wind resources along the coast can be attributed to this area's proximity to the open sea, while scarcer wind resources in the inland part of the state can be attributed to greater surface roughness. Ch. 1 Figure 5, Ch. 1 Figure 6, and Ch. 1 Figure 7 suggest that in the inland part of the state, surface roughness appears to override the positive effects of high topographical elevation on wind speeds.

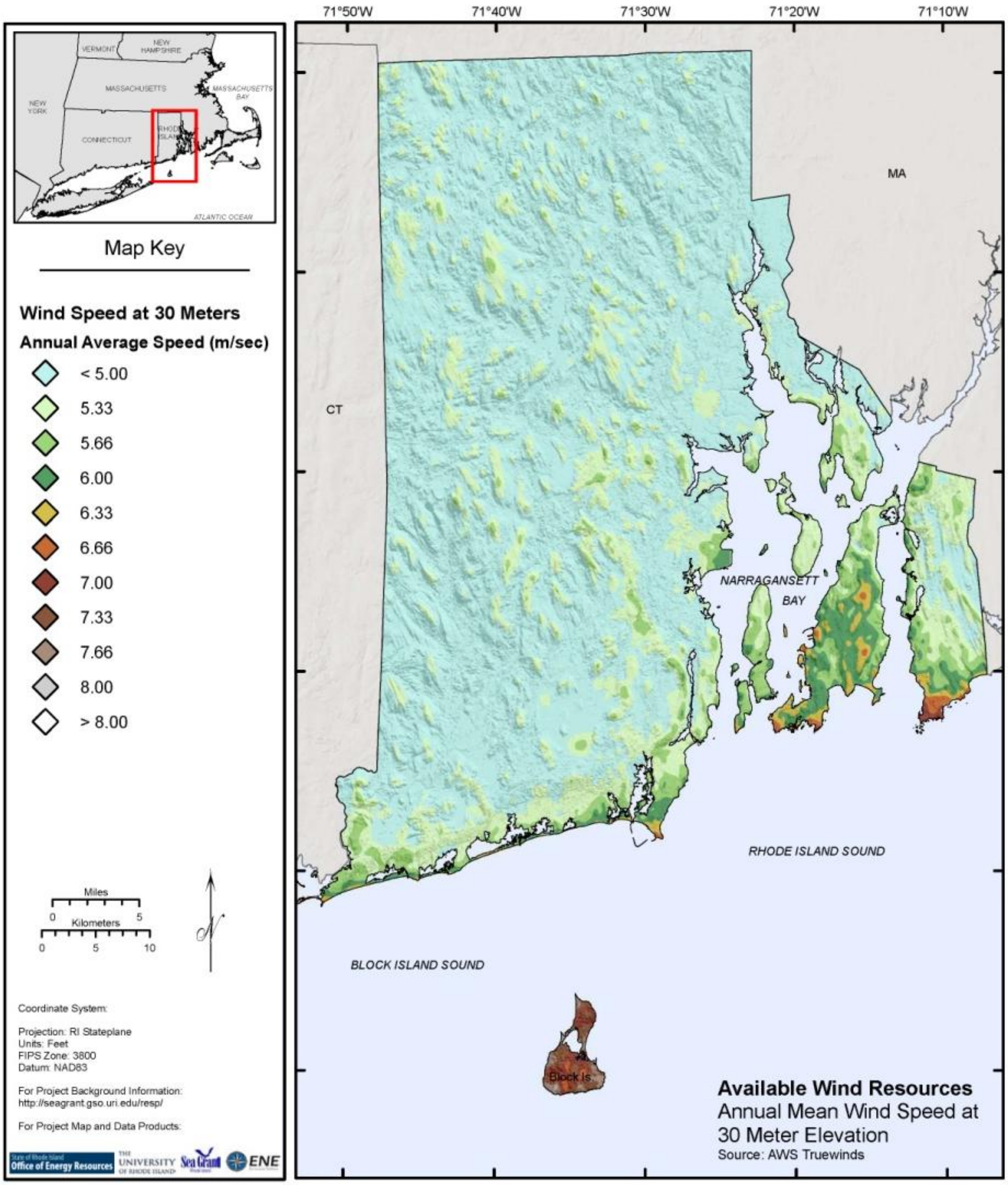
Ch. 1 Figure 5 displays the average annual wind speeds at 80m (262 feet; this is the approximate hub height of a 1.5MW turbine), Ch. 1 Figure 6 displays the average annual wind speeds at 50m (164ft; this is the approximate hub height of a 660-kW turbine), and represents the average annual wind speeds at 30 m (98 ft; this is the approximate hub height of a 100kW wind turbine). Additional wind resource maps and analysis can be found in the RESP technical reports presented in Volume II and online at RI Energy.org.



Ch. 1 Figure 5. Average Annual Wind Speeds at 80m (262ft), as Predicted by AWS Truewind MesoMap.



Ch. 1 Figure 6. Average Annual Wind Speeds at 50m (164ft), as Predicted by AWS Truewind MesoMap.

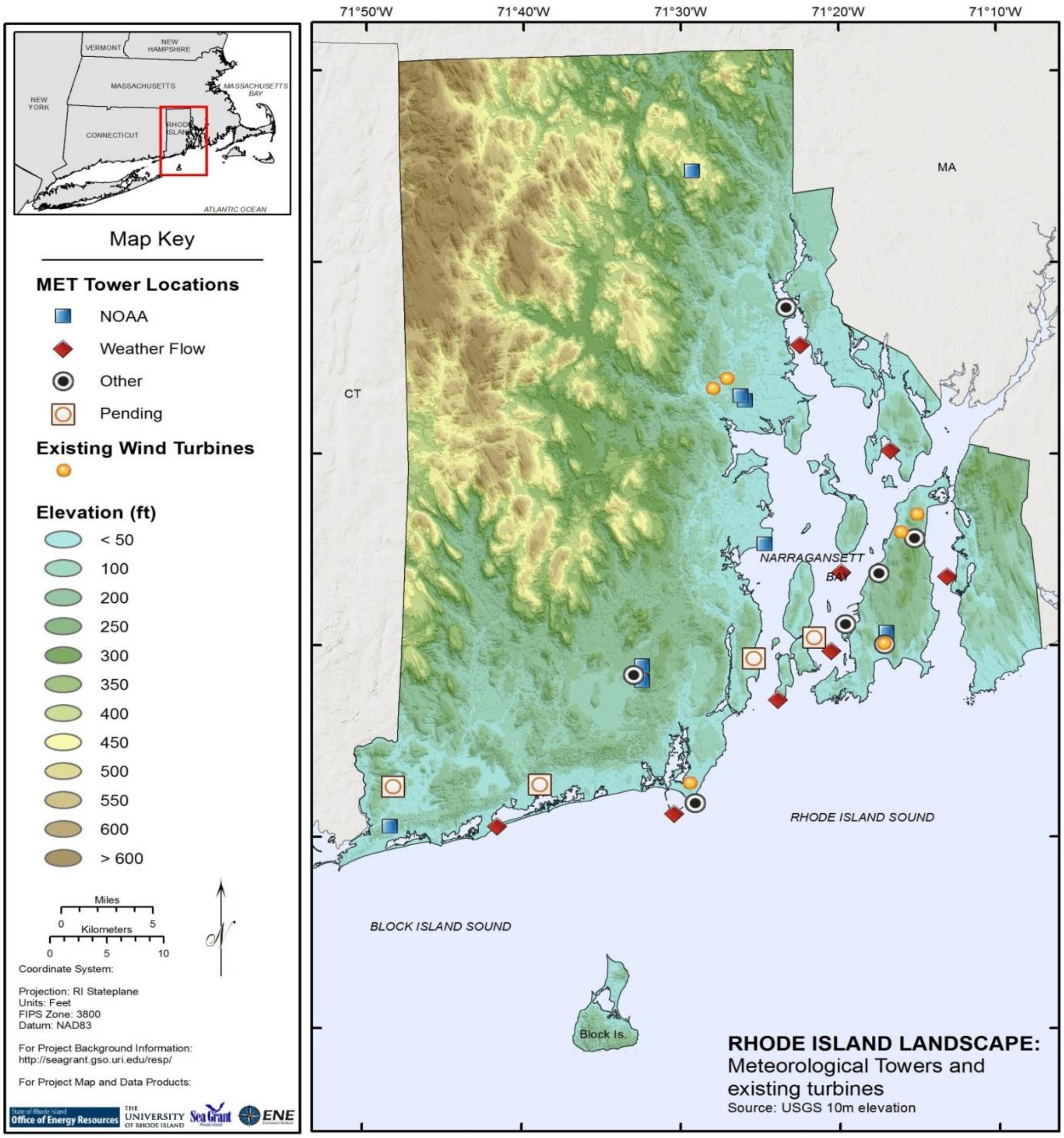


Ch. 1 Figure 7. Average Annual Wind Speeds at 30m (98ft), as predicted by AWS Truewind MesoMap.

2.3 Data on Wind Speeds across Rhode Island

The types of tools that can be used to gather observational wind speed data include anemometers and SODARs. Anemometers serve to gather information on wind speeds over periods of days, weeks, or years. Long-term data sets like those collected by the National Oceanic and Atmospheric Administration (NOAA) often rely on pole-mounted anemometers to collect data at a single elevation, usually near the surface. In contrast, many of the shorter-term data sets available are gathered using multiple anemometers, often mounted on a single meteorological tower, to measure wind speeds at various heights. Because wind speeds increase with elevation, the availability of wind speed measurements at various elevations is useful to accurately assess the characteristics of the wind resource at a proposed wind turbine site. Meteorological towers can also be outfitted with temperature and humidity gauges at the same elevations as anemometers so that wind speed measurements can be correlated with other parameters.

A SODAR (Sonic Detection And Ranging Instrument), on the other hand, uses acoustics to measure wind speeds up to 200 meters (656 feet). SODARs can collect wind data at much higher elevations than would be feasible using meteorological towers. They are also easier to deploy than meteorological towers because they are mobile and do not require permanent installation. A SODAR’s reliance on acoustics rather than a physically mounted instrument mean that it can be set up to gather wind speed data from various elevations in the same location at the same time, making this tool especially valuable for comparing variations in wind speeds with height. One downside of using SODARs is temperature data is not collected at elevation.



Ch. 1 Figure 8. Meteorological Tower Locations in Rhode Island.

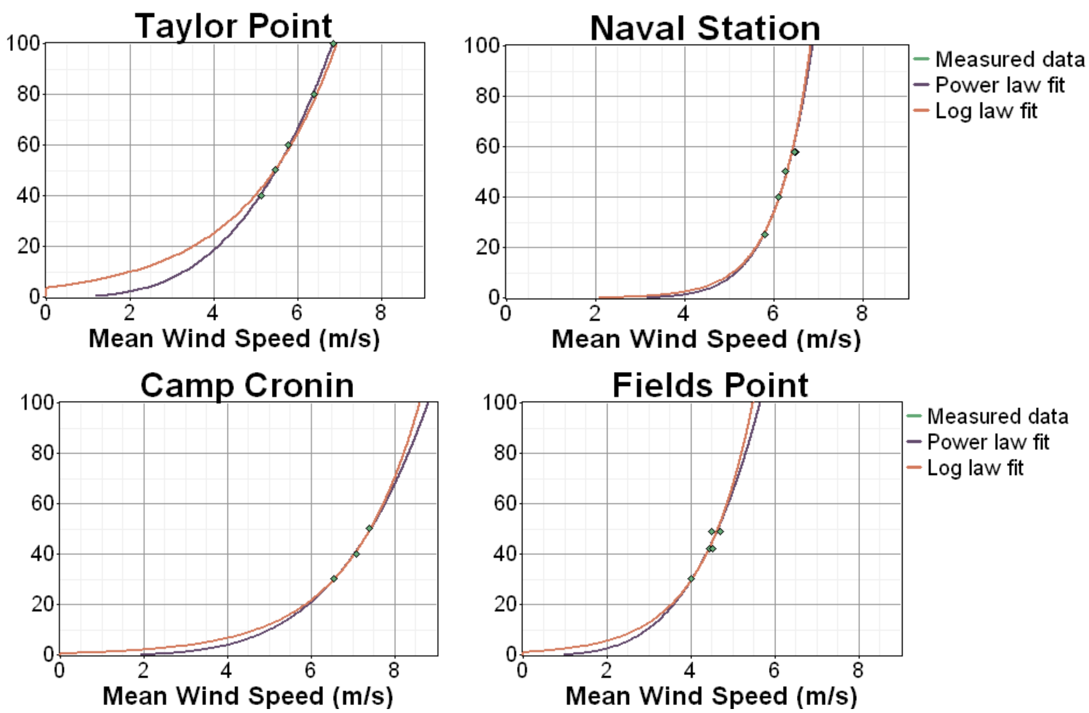
Wind data has been collected around Rhode Island (see Ch. 1 Figure 8). Some data sets are long-term, spanning decades, such as the data collected at the TF Green Airport. Others are much shorter term, spanning two years or less. These various sites and time periods can provide a glimpse into the wind resources in Rhode Island and ground-truth the modeled wind speed estimates provided by the AWS Truewind MesoMap. However, because of the limited amount of data collected this picture is not complete.

Ch. 1 Table 1. Existing Wind Data Used for RESP Resource Assessment.

Location	Source	Time series	Type of data
Fields Point (tower)	Narragansett Bay Commission	March 2007 – November 2007 January 2008 – March 2009	30m (98ft), Paired42m + 49m(138ft + 161ft)
Camp Cronin, Narragansett (tower)	RI DEM	November 2009 – February 2011	30m, 40m, 50m (98ft, 131ft, 164ft)
Newport (tower)	Naval Station	August 2009 – August 2011	Paired 47.5m + 58m (156ft + 190ft); Paired 24m + 40m (79ft + 131ft)
Taylor Point, Jamestown (SODAR)	Jamestown	May 2011 – December 2011	40m, 60m, 200m (131ft, 197ft, 656ft)
URI Bay Campus (tower)	RESP/URI	2012 -	Paired: 40m + 50m + 60m (131ft + 164ft+197ft)
URI Bay Campus (SODAR)	RESP/URI	2012 -	40m, 60m, 200m (131ft, 197ft, 656ft)

Merrill and Knorr (2012) evaluated four existing data sets for the purposes of the RESP. In addition, a new meteorological tower was installed at the University of Rhode Island's Bay Campus in Narragansett and deployed two mobile SODAR units at various sites around the state. Ch. 1 Table 1 shows a list of the various data sets compiled by Merrill and Knorr (2012).[1] The researchers then calculated average wind speed at each height measured, and fit a log profile and power law distribution to each data set to estimate the wind profile with elevation. Ch. 1 Figure 9 shows average wind speeds at measured elevations, power law fit, and log law fit for each location.

[1] The final two listings represent equipment that has been installed but has not produced data yet.



Ch. 1 Figure 9. Vertical Profiles of Wind Speed at Four Selected Sites in Rhode Island. [The green diamond indicates the average speed at each level, and the curves indicate the variation following the log profile and power law distribution.]

Merrill and Knorr (2012) compared data from the four sites providing a preliminary indication of the variation in wind speeds with geography, height, season, and time of day. Results suggested stronger wind speeds at Camp Cronin, weaker wind speeds at Fields Point, and intermediate wind speeds at the Newport Naval Station and Taylor Point. This pattern can be explained by the varying proximity of the four sites to the coast, with sites closer to the ocean displaying higher wind speeds than those further inland.

A comparison of wind speeds during different months of the year indicates a general pattern of weaker winds during summer, strongest winds during spring and fall, and intermediate winds in winter. The Fields Point site presented less pronounced seasonal variation in wind speeds than other three sites. This is most likely due to that site's overall weaker wind environment. Merrill and Knorr (2012) also explored variation in wind shear (i.e., the increase of horizontal wind speeds with elevation) across the four sites. They found that at Fields Point, the wind shear coefficient changes little throughout the year, while the Camp Cronin and Taylor point sites display a greater change. In laymen's terms, the rate of increase in wind speeds with elevation becomes more pronounced during certain times of year; this variation is stronger at Camp Cronin and Taylor Point than at Fields Point.

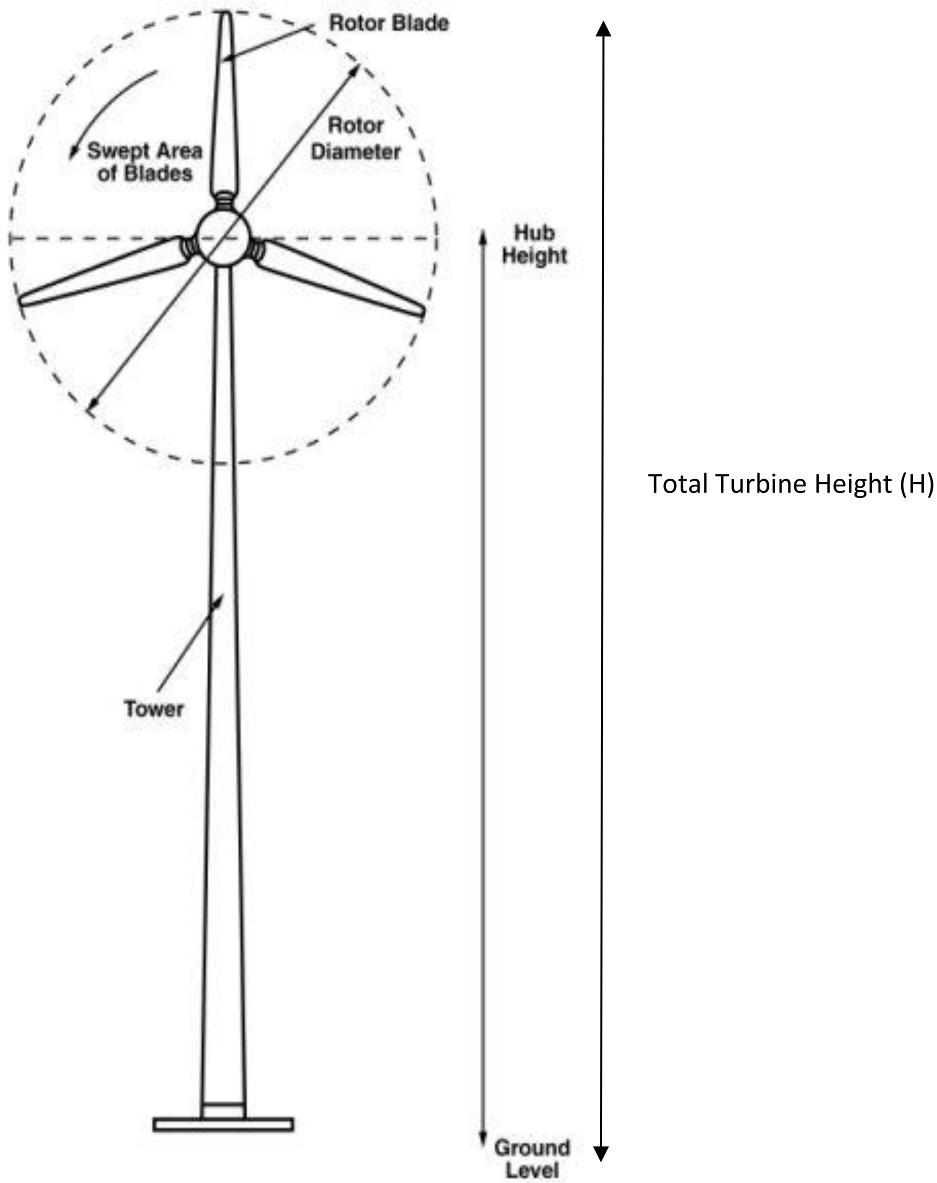
A comparison of wind speeds at different points during the day suggests that the onshore sea breeze flow of wind from the southwest that takes place in the afternoon is greater at Fields Point than for the other three sites. This is most likely because the variation caused by the sea breeze / land breeze cycle is highest as one moves further inland. The results of this analysis can be found in greater detail in Merrill and Knorr (2012).

Analysis of observational data at specific data collection sites can also serve to verify the accuracy of the modeled data that is used to map wind speeds statewide. To assess the accuracy of the modeled data at predicting wind speeds, Grilli *et al.* (2012) compared the AWS TrueWind modeled data reflected in the maps above to existing wind speed measurements collected at eight points across Rhode Island. The results of this comparison show that at any specific location tested, the difference between the AWS TrueWind estimation and actual mean wind speeds ranges from -4.5% to +2.5% in a confidence interval of 95 %. Therefore, if we measure the mean wind speed at any point in Rhode Island there is a 95 % of chance of finding the mean value being in this small interval around the predicted AWS value. This relatively small difference demonstrates that AWS Truewind is a good estimator of the mean wind speed (Grilli et al. 2012). Using accurate modeled wind data is important due to the fact that even small differences in wind speed result in much larger differences in power production because, as a general rule, the power output of a wind turbine increases by the cube of wind speed (Wizelius 2007).

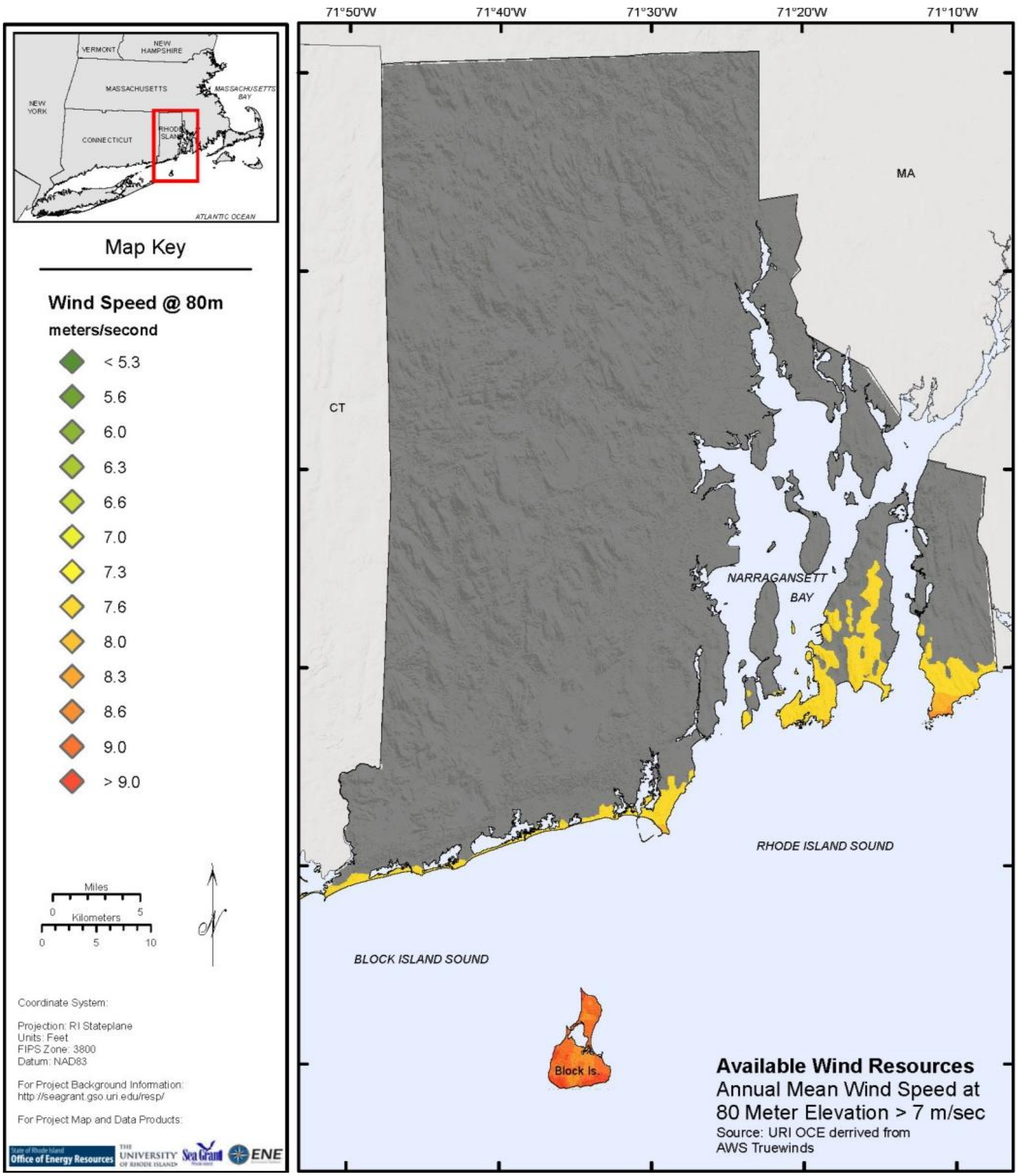
2.4 Assessing Areas for Wind Energy Production

According to the U.S. Department of Energy, wind speeds classified as “fair” or adequate wind speeds for wind energy production are considered to be those greater than 4.5, 5.5, and 7m/sec (10, 12, and 16mph) at 30, 50, and 80m (98, 164, and 262ft) hub heights, respectively (see Ch. 1 Figure 10 for a diagram of turbine measurements). Winds meeting these criteria are classified as Class 3 or higher by the U.S. Department of Energy (see http://www1.eere.energy.gov/wind/wind_potential.html). A typical 1.5 MW wind turbine has a hub height of 80 meters (262 feet). RESP researchers developed a series of maps that explore the distribution of commercially harvestable wind speeds across the state.

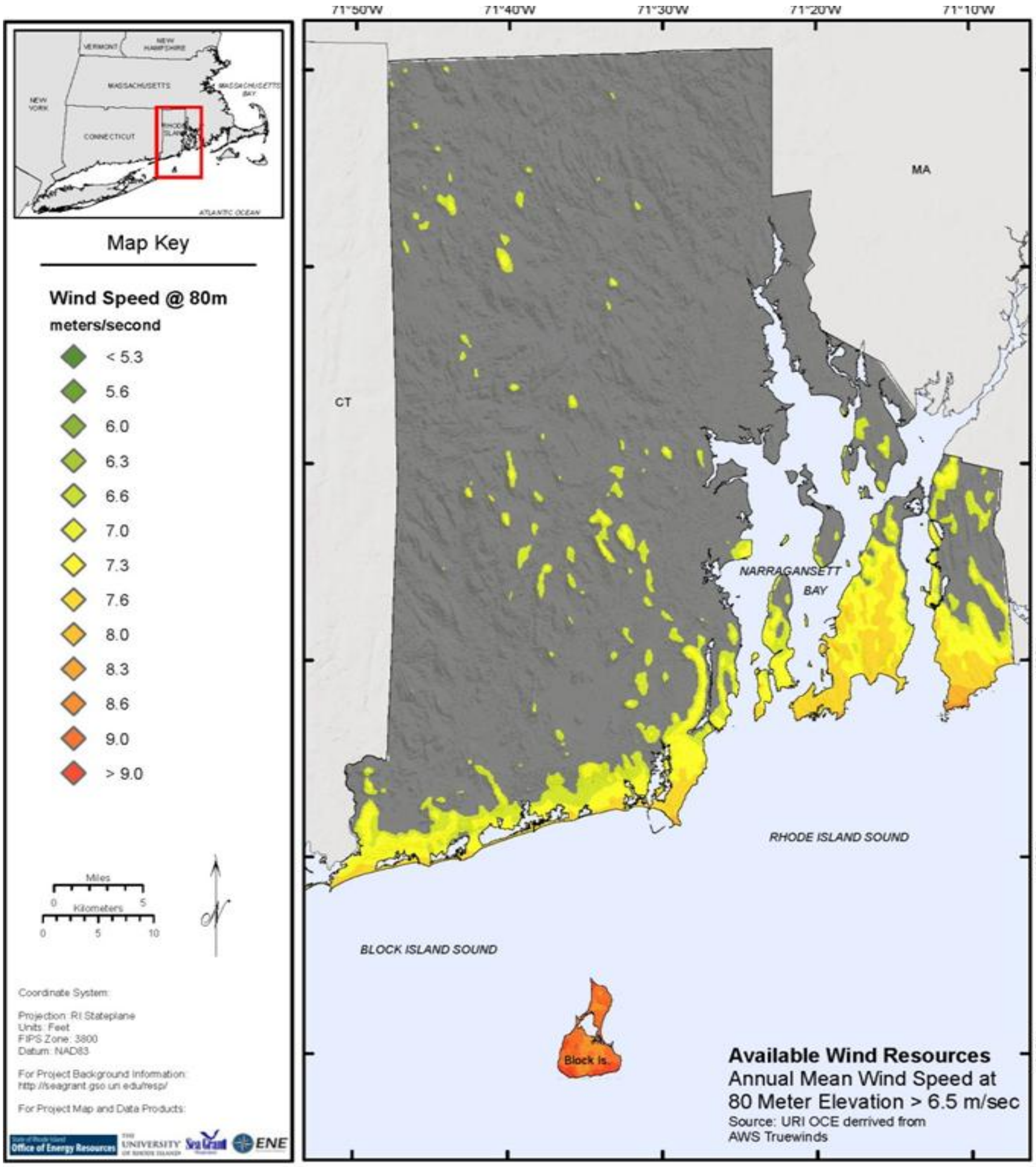
Ch. 1 Figure 11 shows locations in Rhode Island where annual mean wind speeds are over 7m/sec (16mph) at 80m (262ft) hub height, meeting the Department of Energy’s standard for adequate wind resources for development. As the figure shows, only a small portion of the state (e.g., coastal regions and Block Island) exhibits wind speeds that meet this criteria. However, this observation does not necessarily mean that wind energy cannot be developed in other parts of the state, especially as improvements in technology make development more viable in areas with slower average annual wind speeds. Ch. 1 Figure 12 and Ch. 1 Figure 13 show wind speeds in Rhode Island at the 80m (262ft) hub height above 6.5 and 6m/sec (15 and 13mph), respectively.



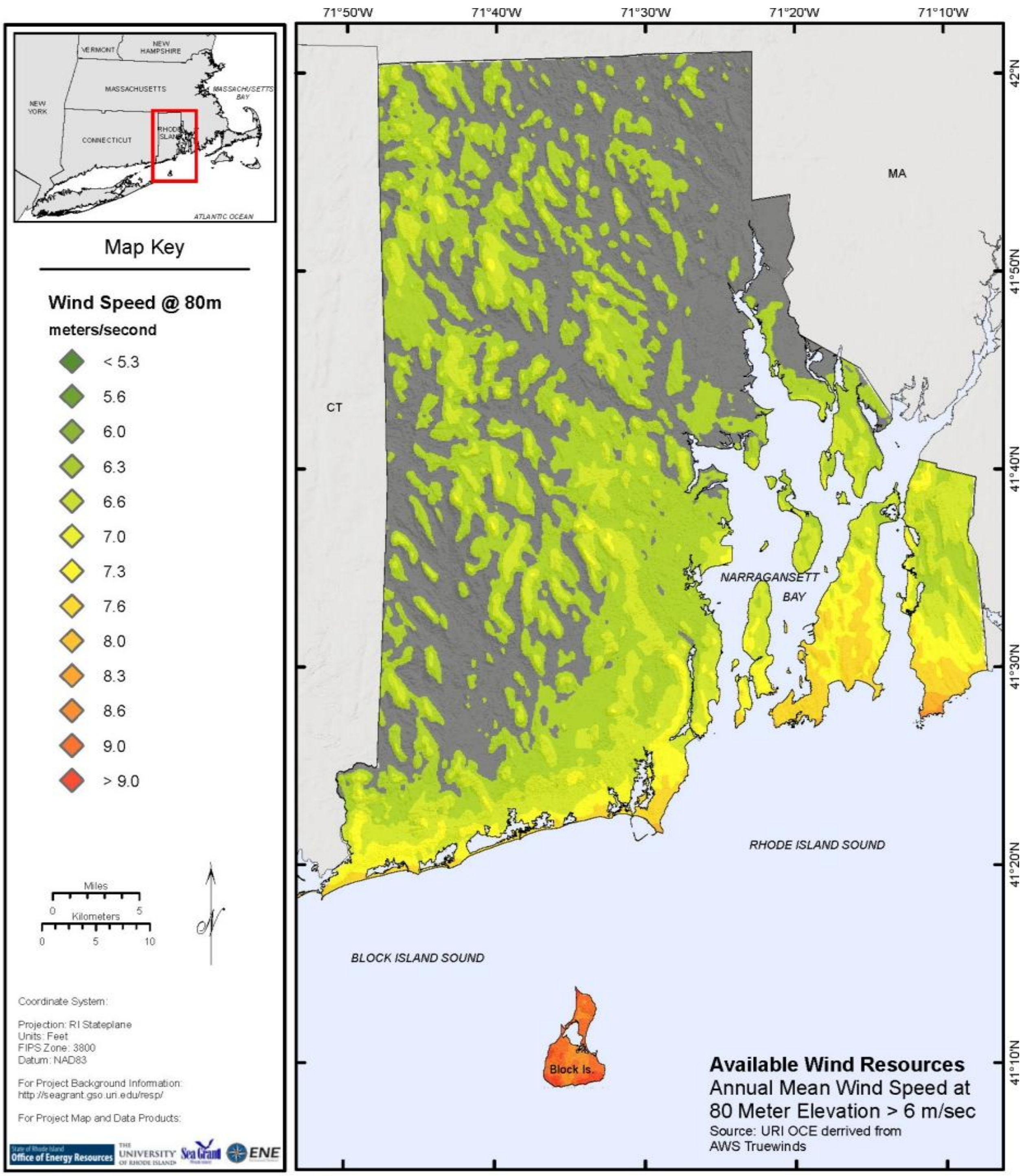
Ch. 1 Figure 10. Wind Turbine Terminology.



Ch. 1 Figure 11. Average Annual Wind Speeds at 80m (262ft) Greater than 7m/sec (16mph).



Ch. 1 Figure 12. Average Annual Wind Speeds at 80m (262ft) Greater than 6.5m/sec (15mph).



Ch. 1 Figure 13. Average Annual Wind Speeds at 80m (262ft) Greater than 6m/sec (13mph).

2.5 Wind Power Production

Potential wind production can be projected at three levels: the theoretical resource, the technical resource, and the practical resource. The available energy production available at each of these levels is progressively smaller than at the previous one, because each level takes into account a greater number of limiting factors than the last. The theoretical resource is the amount of power generated by the wind, or the amount of energy theoretically available at a site if all power were harvestable. The technical wind power resource, in contrast, is a subset of theoretical resource equal to the amount of power that can actually be produced at a location given the characteristics of the extraction device (turbine). Lastly, the practical wind power resource accounts for restrictions on the availability of extractable wind power that result from environmental and social precautions.

Theoretical Wind Resource

The theoretical resource is defined as the maximum amount of energy theoretically possible given the topography, land cover, and atmospheric patterns present at a particular location. In other words, it is the amount of power (measured in power density, or watts/m^2) [2] that would be available at a site if turbines were present to harvest it and if turbines were 100% efficient. The theoretical resource is the standard value used in the wind industry and the one mapped by AWS Truewind. Ch. 1 Figure 14 shows the theoretical resource available at a 30m (98ft) hub height across the state calculated by Grilli *et al*. (2012), based on AWS TrueWind modeled wind speed data (in Watts/$meter^2$).

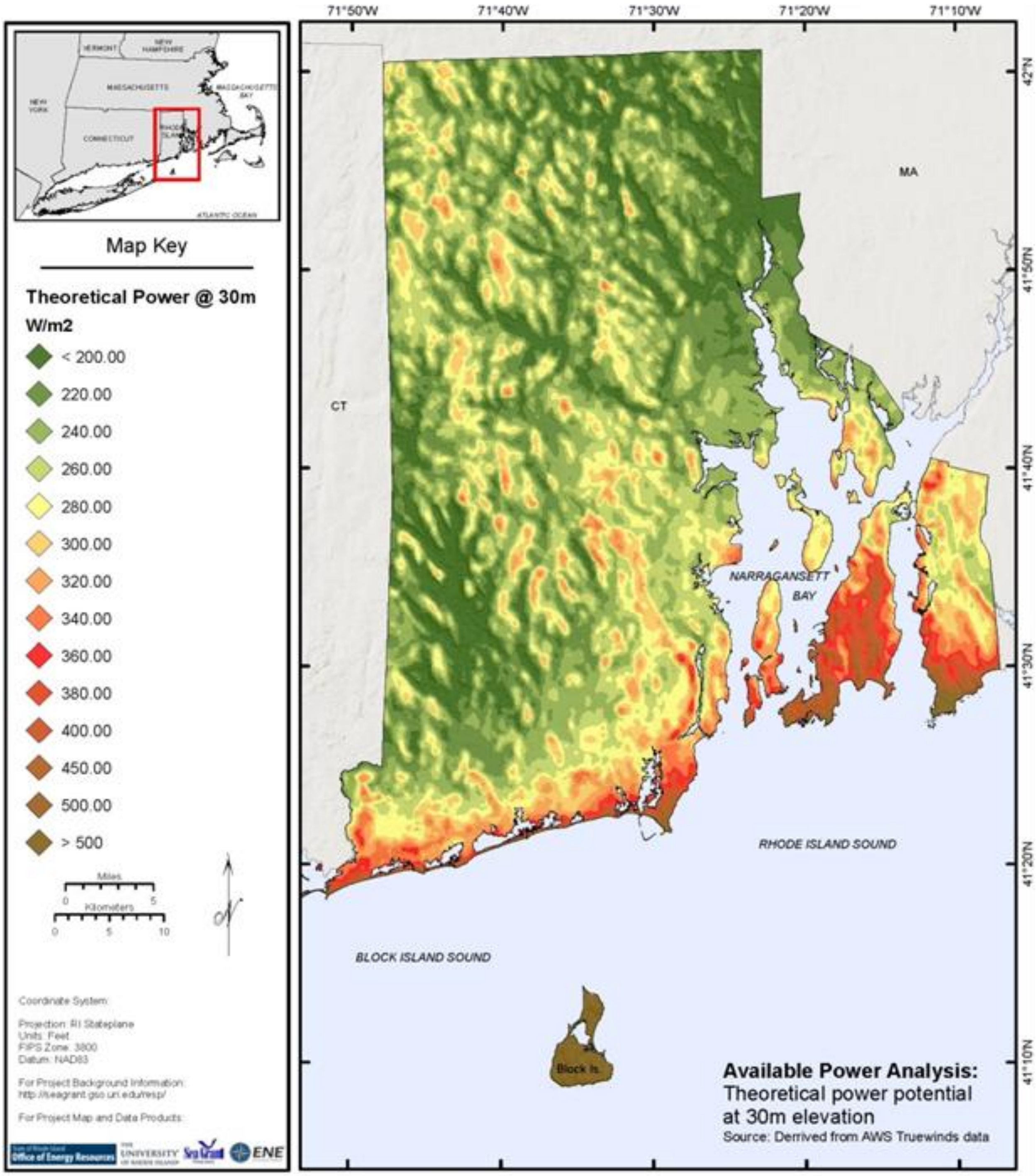
Technical Wind Resource

Like the theoretical resource, the technical resource is measured in power density (watts/m^2). It is calculated by accounting for the following factors:

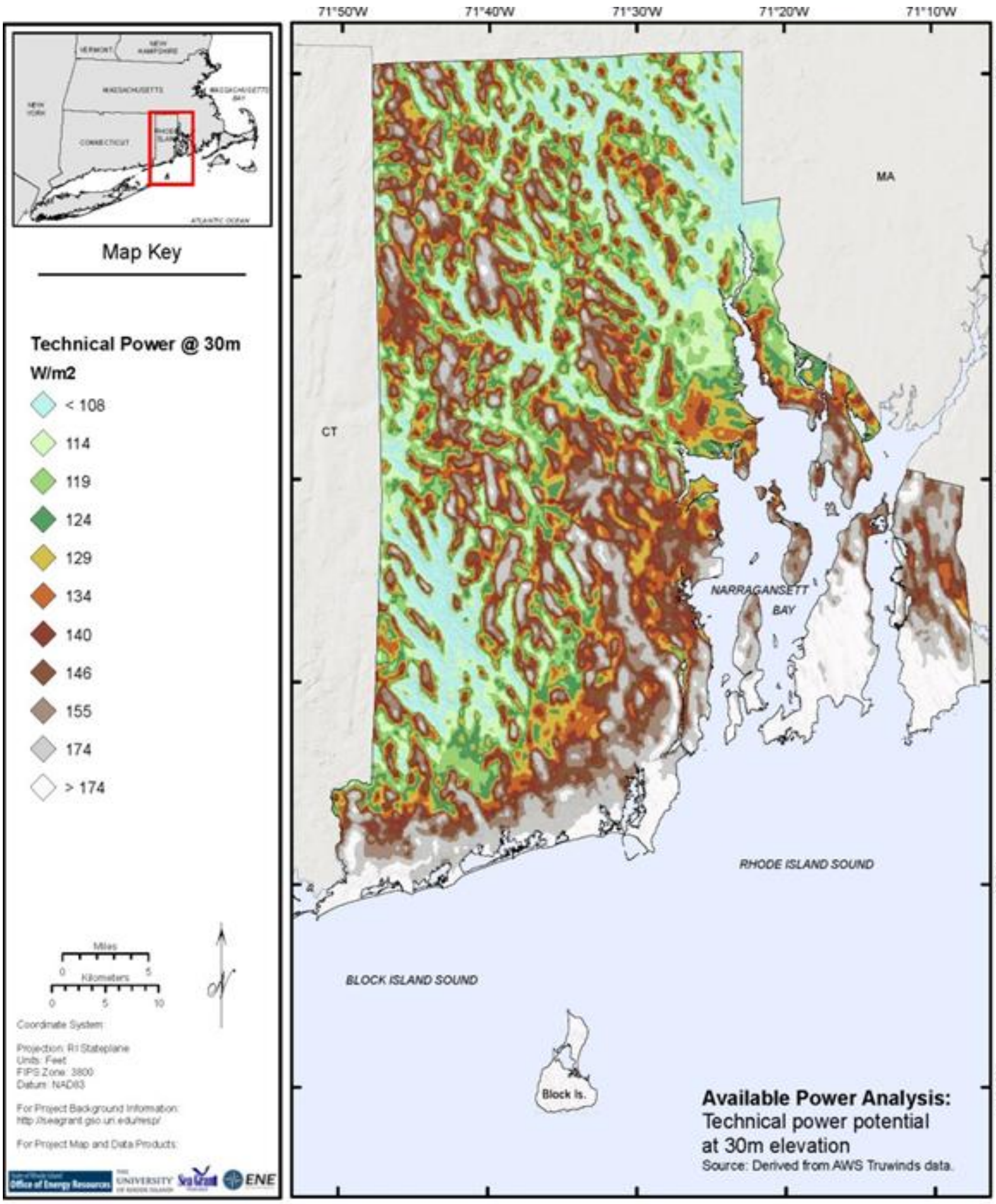
- Betz' Law, which holds that no device can extract more than 59.3 percent of the kinetic energy in wind (this is why wind entering a turbine's rotor flows through the turbine instead of stopping when it hits the rotor);
- Cut-in speed (the minimum wind speed at which a turbine begins to operate; typically between 3-4m/sec, or about 7-9mph);
- Rated power (the wind speed at which the turbine ceases to generate additional energy per m/sec of wind speed; all turbines are engineered for a specific rated power, typically somewhere between 12-17m/sec, or 27-38mph);
- Cut-out speed (the maximum wind speed at which a turbine operates before shutting down for safety reasons, typically around 25m/sec, or 56mph);
- Inefficiencies due to rotor blade friction and drag, gearbox energy losses, generator and converter losses, that reduce the power delivered by a wind turbine.

Ch. 1 Figure 15 illustrates the technical power available at 30 m (98 feet) elevation across the state calculated by Grilli *et al*. (2012), based on AWS TrueWind modeled wind speed data.

[2] Power density measured in watts/m^2 refers to the energy of the wind hitting a vertical cross section found within the vertical plane circumscribed by the turbine's rotor.

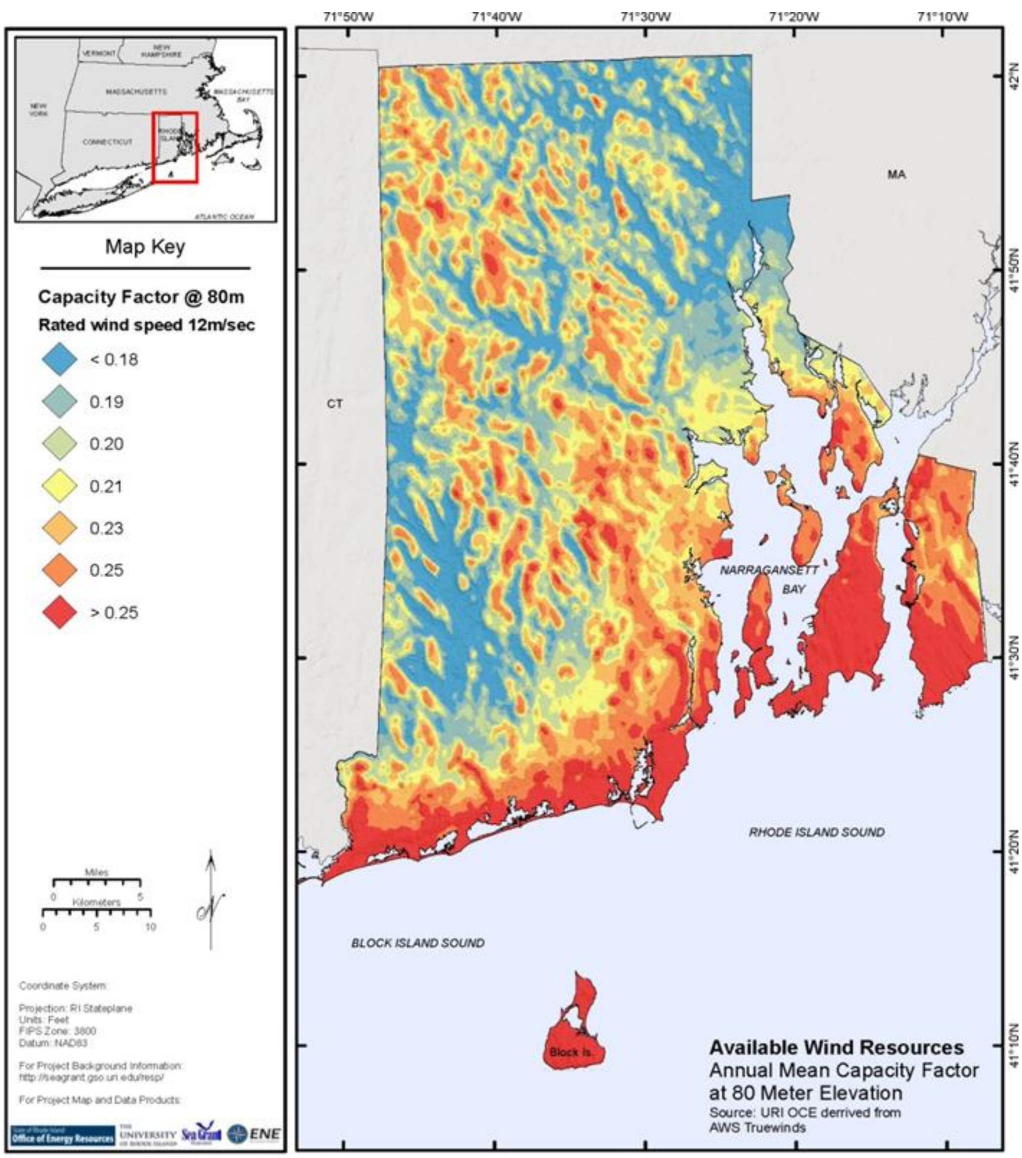


Ch. 1 Figure 14. Theoretical wind power (Watts/meters2) that can be generated at a 30m (98ft) hub height elevation.



Ch. 1 Figure 15. Technical wind power (watts/meter2) that can be generated at a 30m (98ft) hub height elevation (assuming 14 m/s [31mph] rated speed, cut in and cut out, 3.5 and 25m/s [8 and 56mph] respectively).

Technical resource can also be visualized by looking at a variable called capacity factor. Capacity factor is the ratio of the actual energy produced during a given time period to the hypothetical maximum energy that could possibly be produced during that time if the turbine were running at rated speed 100% of the time. Capacity factor is a function of the frequency distribution of wind speeds at a given site, the height of the turbine, and the rated speed of the turbine. From an economic perspective, generally capacity factors above 0.25 are considered viable (AWEA 2009), however there may be exceptions to this rule based on the economics of a specific project. Ch. 1 Figure 16 shows capacity factors across Rhode Island at 80m (262ft) for a turbine with a 12m/sec (27mph) rated speed. In keeping with the wind resource maps shown previously, coastal areas show the greatest capacity factors.



Ch. 1 Figure 16. Annual mean capacity factor at 80m (262ft) hub height.

Practical Wind Resource in Rhode Island

Practical wind power resource is a further refinement of the estimation of technical wind power resource that accounts for restrictions on the availability of extractable wind power due to environmental and social considerations. There is no single, scientifically determined estimate of practical resource for a given location. Rather, the practical resource at a site is determined by a wide array of factors that can be customized to meet the needs of individual communities. These include tolerance of visual impacts, bird and bat impacts, noise and shadow flicker, and many other considerations detailed in Section 3 of this chapter. Section 4 of this chapter further explores the practical wind resource available in Rhode Island by presenting environmental and social considerations that may make some sites less feasible to develop.

3. Potential Effects of Wind Energy Development

The development of wind energy projects in Rhode Island is a novel enterprise, and it has the potential to impact surrounding natural resources and nearby residents in novel ways. While some of these potential impacts are common to the development of any large structure, others are unique to wind turbines, and present challenges previously unknown in Rhode Island. The type and magnitude of an individual project's effects vary based on the technology used and the characteristics of the turbine site. This section discusses those concerns, and presents mitigation measures available to eliminate or reduce their potential impact.

3.1 Structural Failures and Blade Throw Considerations

Section Summary

- Structural failure of wind turbines is rare but not impossible.
- Publically available data on wind turbine failure rates is very limited. Therefore, calculating failure rates for current wind turbines technology can be difficult, as not all incidents are reported, and there is no centralized regulatory body charged with compiling and verifying failure incidents in the United States.
- If a blade fragment detaches from a turbine, the location of landfall is controlled by the angular velocity of the rotor, the position of the breaking point on the blade, and the size of the thrown piece. This relationship can be used to identify an appropriate setback from homes and other populated sites given different risk tolerances.
- Similar to other structures icing may occur on wind turbines. When ice falls or is flung from a moving blade, it can potentially become dangerous.
- Rhode Island experiences weather conditions conducive to icing of turbine blades about 0-2 times annually. During those times, there is a risk of ice throw, particularly if a turbine continues to operate.
- The potential risk associated with ice throw can be minimized through setbacks, shutdown procedures, and ice detection mechanisms.

As with any technology involving moving parts and operational components under stress, wind turbines present a risk of structural failure. Turbines can fail in a number of different ways: towers can bend or collapse, nacelles can topple, anemometers and bolts can fall, and blades can break or be thrown. Structural failures in turbines may result from extreme environmental events, improper design or manufacturing, failures in turbine control/safety system, and human error.

Nonetheless, while structural failures are possible, they are rare. As of March 2012, the only fatal injuries known to occur worldwide due to structural failure of wind turbines have been experienced by turbine technicians or associated personnel (Caithness Wind Information Forum, 2012). However, it should be noted that calculating failure rates for wind turbines is difficult, as not all incidents are reported, and there is no centralized regulatory body charged with compiling and verifying failure incidents in the United States. One of the most robust resources detailing cases of structural failure in wind turbines is provided by the Caithness Wind Information Forum

(CWIF), which records information worldwide on turbine accidents and failures reported between 1970 and 2012 (see http://www.caithnesswindfarms.co.uk/page4.htm). The Caithness Wind Information Forum data is not comprehensive, as it only documents those failures that are voluntarily reported. In addition, the accident summary reports provided in this database should be used with caution as some incidents classified as wind turbine accidents may be misleading.[3]

One highly cited study examining the failure frequency of blades, towers, and other parts of a particular wind turbine was conducted by Rademaker and Bramm (2005) at the Energy Research Center of the Netherlands (ECN). This study examined data collected in Germany and Denmark by the ISET (Institut für Solare Energieversorgungstechnik) and the EMD (Energie-og Miljødata). The study reviewed failure information from 4,400 turbines, with over 43,000 years of operation among them, operating from 1984 to 2001. Ch. 1 Table 2 summarizes the results of this study. Analysis of this dataset calculated that the probability of detachment for a whole blade and blade fragment (within a 95% confidence interval) equal 8.4 in 10,000 and 2.6 in 10,000, respectively.

It should be stressed that the findings presented in Rademaker and Bramm (2005) are based on turbine models installed from 1984 to 2001, and reflect the general probability and risk based on machinery from that time period. As with any technology, the past decade of advancement has led to improvements that will likely make turbines safer. For example, remote monitoring, automatic shutdown capabilities or blade feathering, more efficient turbines that operate at lower RPMs (rotations per minute), and improved blade composite materials are all advances in technology that are aimed at improving turbine performance, as well as lowering risk and safety concerns.

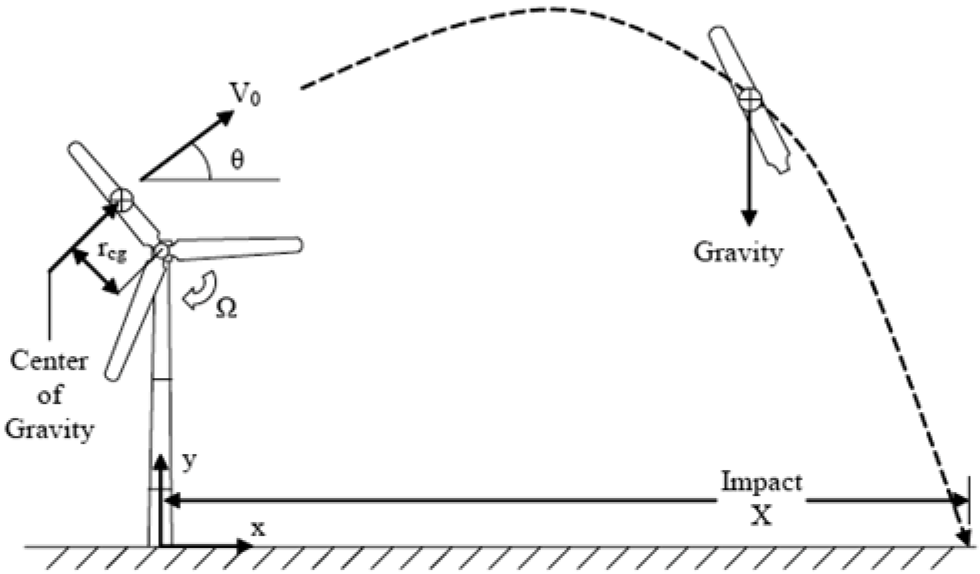
[3] For one example, on its accident summary report, Caithnesswindfarms.co.uk refers to an accident in which "17 bus passengers were killed in one single incident in Brazil in March 2012." The report fails to mention that the "Wind Turbine Accident" to which it refers involved a bus crossing lanes and hitting a truck carrying wind turbine parts. The accident was found to be the fault of the bus driver, and as such should not be labeled a "fatal wind turbine accident" without qualification.

Ch. 1 Table 2. Assessment of Wind Turbine Failures using Danish and German Data from 1984-2001 as Reported in Rademaker and Bramm (2005).

Part	Failure frequency per turbine per year			Maximum throw distance [m] (reported and confirmed)
	Expected Value	95% upper limit	Recommended Risk Analysis Value [1/yr]	
Entire blade	$6.3*10^{-4}$	$8.4*10^{-4}$	$8.4*10^{-4}$	150
Nominal rpm			***$4.2*10^{-4}$***	
Mechanical braking			***$4.2*10^{-4}$***	
Overspeed			***$5.0*10^{-6}$***	
Tip or piece of blade	$1.2*10^{-4}$	$2.6*10^{-4}$	**$2.6*10^{-4}$**	500
Tower	$5.8*10^{-5}$	$1.3*10^{-4}$	**$1.3*10^{-4}$**	Shaft height + half diameter
Nacelle and/or rotor	$2.0*10^{-4}$	$3.2*10^{-4}$	**$3.2*10^{-4}$**	Half diameter
Small parts from nacelle	$1.2*10^{-3}$	$1.7*10^{-3}$	**$1.7*10^{-3}$**	Half diameter

While the longest distance reported for the throw of a broken blade or blade fragment in Rademaker and Bramm's (2005) dataset were 150 meters (492 feet) and 500 meters (1640 feet), respectively, blades and blade fragments tend to fall closer to the turbine base (California Energy Commission (2006). Where tower collapses and nacelle failures occurred within Rademaker and Bramm's (2005) dataset, the parts were recorded as falling within a radius less than or equal to the height of the turbine.

Rogers *et al*. (2011) further examined blade throw distances using the same dataset compiled by Rademaker and Bramm (2005). Their analysis concluded that the probability of a part falling within a certain distance from a turbine is driven less by the size of the turbine and more by the release velocity of the blade fragment and, in turn, by the angular velocity of the rotor, the position of the breaking point on the blade, and the size of the thrown piece (Rogers *et al.* 2011; see Ch. 1 Figure 17).



Ch. 1 Figure 17. Rogers et al. (2011) Analysis of Blade Throw Dynamics.

Setback distances for public safety reasons have traditionally been based on the height of the turbine (e.g. 1.5 times the total turbine height). However, the analysis performed by Rogers *et al.* (2011), combined with incidents reported in Rademaker and Bramm (2005) and in the CWIF database, illustrate that it is possible for blade fragments to be thrown greater distances than those estimated using turbine height alone. A more mathematical approach to determining appropriate setbacks performed by Rogers et al. (2011) took into account variables related to the turbine height, blade fragment size, and probability of occurrence, to calculate the specific radius of risk corresponding with a particular project. However, a key challenge with the Rogers et al. (2011) analysis is defining a risk level that can be agreed upon by all those involved in siting decisions. In addition, in order to obtain realistic results from this analysis that applies to the turbine technology being used today, accurate blade failure statistics should be used. Unfortunately, the best available structural failure data is presented in Rademaker and Bramm (2005) covering turbines operating between 1984 and 2001 and therefore may not be representative of the technology used today. If the Rogers et al. (2011) methodology were to be applied in order to establish a setback distance, it is recommended that more recent failure data be used in the analysis.

3.2 Icing Considerations

SECTION SUMMARY

- Similar to other structures icing may occur on wind turbines. When ice falls or is flung from a moving blade, it can potentially become dangerous.
- Rhode Island experiences weather conditions conducive to icing of turbine blades about 0-2 times annually. During those times, there is a risk of ice throw, particularly if a turbine continues to operate.
- The potential risk associated with ice throw can be minimized through setbacks, shutdown procedures, and ice detection mechanisms.

Wind turbines may accumulate a surface coating of ice during certain atmospheric and meteorological circumstances, such as ambient temperatures near freezing (0°C / 32°F) combined with high relative humidity, freezing rain, or sleet. Under such icing-prone climatic conditions, two types of risks may occur. If a wind turbine continues to operate, ice fragments clinging to turbine blades may be thrown outward due to aerodynamic and centrifugal forces. When a turbine is shut down or idling, ice fragments may fall downward from the blades or other parts of the turbine (as they may from other structures that experience icing).

A first question to consider when evaluating the potential occurrence of ice fall and ice throw incidents at a location is how frequently icing conditions occur. Although Rhode Island's low topography and temperate latitude are not highly conducive to conditions in which ice can accrete to rotor blades, these conditions do occur in Rhode Island about 0-2 times annually (University of Massachusetts Amherst, 2000; NCDC, 2008). The University of Massachusetts at Amherst calculated a 0.88 annual probability of occurrence of an ice storm capable of producing ice thicker than 0.63cm (0.25in) or almost once per year, in New England (Lacroix 2000). However, local icing conditions may vary considerably over short distances due to elevation. It is recommended that data at a specific location be used to determine incidences of icing if possible (Baring-Gould, 2006).

A second question to consider is how far ice fragments are likely to fall or be thrown in the event that icing conditions do occur. Surveys and modeling suggest that in extremely rare instances, ice fragments may be thrown as far as hundreds of meters from the base of a turbine (Seifert *et al.* 2003; Cattin *et al*. 2005). However, if a turbine is shut down during icing conditions, the ice throw zone is much smaller. An assessment of icing risk performed for the Canadian Wind Energy Association estimates that only very high winds can cause fragments of significant mass to be blown more than 50m (164ft) from the base of a modern 2MW turbine while the turbine is stationary (LeBlanc 2007). There have been zero (0) reported fatalities to the public resulting from ice thrown from wind turbines (Morgan et al. 1998); this fact, however, does not imply no risk to public safety.

Icing of turbines and the impacts of icing can be managed through ice detection mechanisms, signage and visible warnings, setbacks, and most importantly, proper operating and shutdown procedures during icing events.

In order to ensure that a turbine does not operate during icing conditions, the turbine must have an adequate icing detection system. Icing detection technology is a relatively new area of research, but detection systems are already in use commercially (LeBlanc 2007). These systems can be set up to trigger automatic or manual shutdown of a turbine or to activate blade heating systems that inhibit icing (LeBlanc 2007). The most widely available type of icing detection systems is mounted to the nacelle of a turbine and utilizes an ultrasonic vibrating probe; when the probe becomes coated with ice, its vibration slows, signaling to the instrument that icing has occurred (LeBlanc 2007). Other forms of ice detection system include the installation of cold-tolerant anemometers to measure variances in the relationship between detected wind speed versus power generation and vibration sensors to detect rotor imbalances (General Electric 2000).

3.3 Acoustic Impacts

SECTION SUMMARY

- Wind turbines produce noise through the rotation of blades and operation of the generator.
- Turbines can produce white noise (broadband noise), tonal noise, impulsive noise (“swishing”), low-frequency noise, and infrasound.
- Turbine noise dissipates with distance from the turbine, but is also affected by the physical conditions of a project location including topography, ground cover, wind speed and direction. As a result, noise impacts may vary in a given location and over time. This can make setting noise standards or regulatory thresholds difficult.
- Low frequency noise (100Hz-20Hz) and infrasound (below 20Hz) emitted from wind turbines are becoming an increasingly studied topic. Within the scientific community, there is not yet complete consensus on the impact of infrasound from wind turbines on humans. Many researchers state that infrasound in the areas surrounding wind turbines are at levels inaudible to humans, and that there a lack of medical evidence to suggest any health effect associated with wind turbine infrasound, while others suggest that even at inaudible levels infrasound may have an effect on the human ear.
- Background noise is an important factor to consider when predicting the acoustic impacts of wind turbines. Where ambient noise levels are high, as in densely populations or industrial zones, turbine noise is less audible. Furthermore, during times of the day when ambient noise levels are lowest (e.g. at night between midnight and dawn) turbine noise may be most noticeable.

- Wind turbine noise can be considered annoying. This is a highly subjective and individualized impact, and can be a significant nuisance to those people bothered by it.
- The level of annoyance experienced by people living in proximity to a wind turbine varies widely, and is often correlated with general attitudes towards the turbine in question, visibility of the turbine, and experience of shadow flicker effects caused by the turbine.

Of the issues raised by community members when utility-scale wind turbines are proposed or installed in residential or rural areas, noise is a primary concern, especially for residents whose homes are closest to the turbine(s) (AEI, 2012). This section describes the potential sources of noise from a wind turbine, the types of noise produced, and what is currently known about potential health impacts to surrounding residents. Generalizing noise impacts is difficult as site-specific conditions that vary by project location and time of day or year greatly influence the acoustic impacts experienced. While the noise produced by a wind energy project will vary based on the size and specifications of the turbine(s), the impacts to the surrounding area will also vary based on site-specific conditions including the ambient noise levels, the topography, wind speed and direction, etc. Therefore, the noise impacts of two identical turbines installed in two different locations will vary based on the physical conditions of the area.

Wind turbine noise can result from both mechanical and aerodynamic operation of a turbine. Mechanical noise can be caused by the gear box, generator, yaw drives, cooling fan, hydraulics, or other parts of the wind turbine. Aerodynamic noise is caused by interaction of the turbine blades and the wind (see Ch. 1 Table 3). Several different types of sound can result from wind turbine operation. Broadband noise, also called "white noise," is composed of many frequencies in the audio spectrum greater than 100Hz. Wind turbines produce broadband noise as blades interact with the air, and such noise is experienced as a "whooshing" sound when the wind is blowing. Tonal noise, also called pure tones, is a constant hum occurring at a distinct frequency. Turbines produce tonal noise (or "pure tones"), a constant hum occurring at a distinct frequency. Tonal noise may result from the mechanical operations of wind turbine components, such as meshing gears (RERL 2006). Pure tones are more noticeable when wind speeds are low, since high wind speeds lead to high aerodynamic turbine noise and ambient noise that obscures them. Low-frequency noise measuring between 20 and 100Hz is produced by the aerodynamic operation of wind turbines, and measures 20-100Hz. Infrasound is a type of low-frequency noise produced by wind turbine operation, and is below 20Hz. Infrasound is generally inaudible to humans, but can cause a sensation of pressure in the eardrums (Møller and Pedersen, 2011).). However, if the level is sufficiently high (above 90dB) humans may perceive infrasound. Infrasound is discussed in more detail later in this section. Finally, turbines produce impulsive noise, which is characterized as "short acoustic impulses or thumping sounds that vary in amplitude with time" and "is caused by the interaction of wind turbine blades with disturbed air flow around the tower of a downwind machine" (RERL 2006). Ch. 1 Table 3 presents a synopsis of the types of noise typically produced by wind turbines. The nature of the sound produced by a turbine is to some degree influenced by the design of the turbine (MA DEP and MA DPH 2012).

Ch. 1 Table 3. Sources and Types of Noise Potential Produced by a Wind Turbine (Potty and Miller, 2012; Rogers, 2006).

Possible Sources of Noise from a Wind Turbine	• **Mechanical Noise**: caused by the gear box, generator, yaw drives, cooling fan, hydraulics, etc. • **Aerodynamic Noise**: caused by the interaction of the turbine blades with the wind and therefore is dependent on wind and rotor speed
Possible Types of Noise Produced by a Wind Turbine	1. **Broadband Noise:** This is sound characterized by a continuous distribution of sound pressure with frequencies greater than 100Hz. It is often caused by the interaction of wind turbine blades with atmospheric turbulence, and also described as a characteristic "swishing" or "whooshing" sound. 2. **Tonal Noise:** The "hum" or "pitch" occurring at distinct frequencies that results from operation of machinery. 3. **Low Frequency:** Sound with frequencies in the range of 20 to 100Hz is mostly associated with downwind rotors (turbines with the rotor on the downwind side of the tower). It is caused when the turbine blade encounters localized flow deficiencies due to the flow around a tower. 4. **Infrasound:** Subset of low-frequency noise (below 20Hz), generally inaudible except at high amplitudes (above 90dB). 5. **Impulsive:** This sound is described by short acoustic impulses or thumping sounds that vary in amplitude with time. It is caused by the interaction of wind turbine blades with disturbed air flow around the tower of a downwind machine.

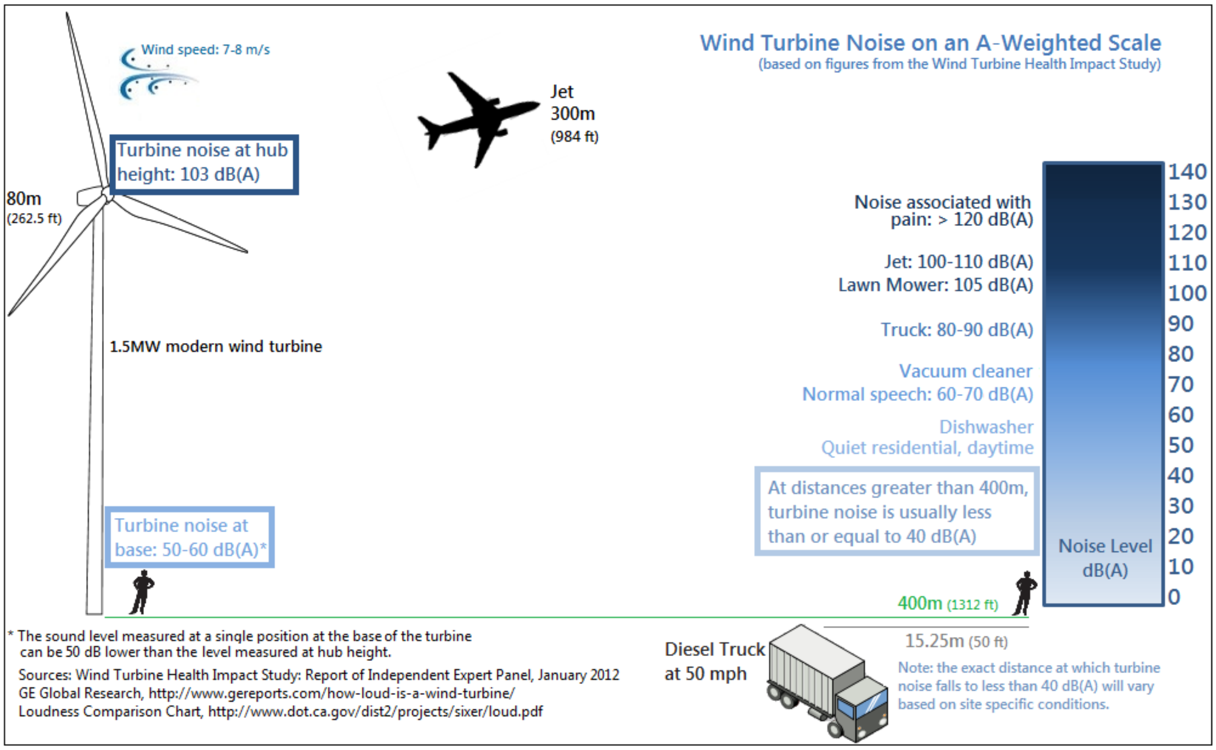
Audible Noise Produced by Wind Turbines

Humans can hear sounds at frequencies from about 20Hz to 20,000Hz, though we hear sounds best at around 3,000 to 4,000Hz, where human speech is centered (MA DEP and MA DPH 2012). To evaluate the experience of noise an A-weighted scale is typically used, which "approximates the response of the human ear to sounds of medium intensity" (RERL 2006). The range of human hearing on an A-weighted scale occurs between 20 dB(A) and about 140 dB(A). This range and examples of sound pressure levels produced by several familiar activities can be seen in Ch.1 Table 4.

Ch. 1 Table 4. Typical Sound Pressure Levels Associated with Familiar Activities (Potty and Miller 2012).

A weighted sound level (dBA)	Source of Noise
110-120	Discotheque, rock-n-roll band
100-110	Jet flyby at 984ft (300m)
90-100	Power mower, cockpit of light aircraft
80-90	Heavy truck at 40mph (64km/h) at approximately 50ft (15m), food blender, motorcycle at 15m (50ft)
70-80	Car at 62mph (100 km/h) at 7.6m (25ft), clothes washer, TV audio,
60-70	Vacuum cleaner, air conditioner at 6m
50-60	Light traffic at 30m (98ft)
40-50	Quiet residential – daytime
30-50	Quiet residential – nighttime
20-30	Wilderness area
Note: This table does not compare wind turbines to other sources of noise in terms of low frequency noise or infrasound. The dB(A) scale is a logarithmic scale. A sound 10 dB(A) higher than another has 10 times the energy, and is generally perceived as being twice as loud. Generally, human ears do not perceive a different in sound level between two noises unless the difference measures at least 3 dB(A).	

While the volume of sound produced by a turbine varies as a function of the design and rated power of the turbine, a typical modern utility scale wind turbine (80 m) produces a sound pressure level on the order of 103 dB(A) at hub height, with wind speeds of about 7-8 m/s. At the base of the turbine, the experience of sound can be 50 dB(A) less than that occurring at the turbine's hub height. The perceived sound decreases rapidly with the distance from the wind turbines. Typically, at distances larger than 400 m, sound pressure levels for modern wind turbines are less than 40 dB(A), which is below the level associated with annoyance in the epidemiological studies reviewed. (MA DEP and MA DPH 2012). However, the exact distance at which sound levels of 40dB(A) will vary based on site specific conditions (e.g. based on topography, ground cover, wind direction, etc.), and in some instances may take multiple times that distance to reach (AEI, 2012) Ch. 1 Figure 18 compares the audible noise produced by a wind turbine at hub height, base, and at 40dB(A) to everyday experiences of noises on an A-weighted scale.



Ch. 1 Figure 18. Wind turbine noise as measured at hub height, turbine base, and at a distance of 400m on an A-Weighted scale. This comparison is based primarily on figures from the Wind Turbine Health Impact Study, January 2012.

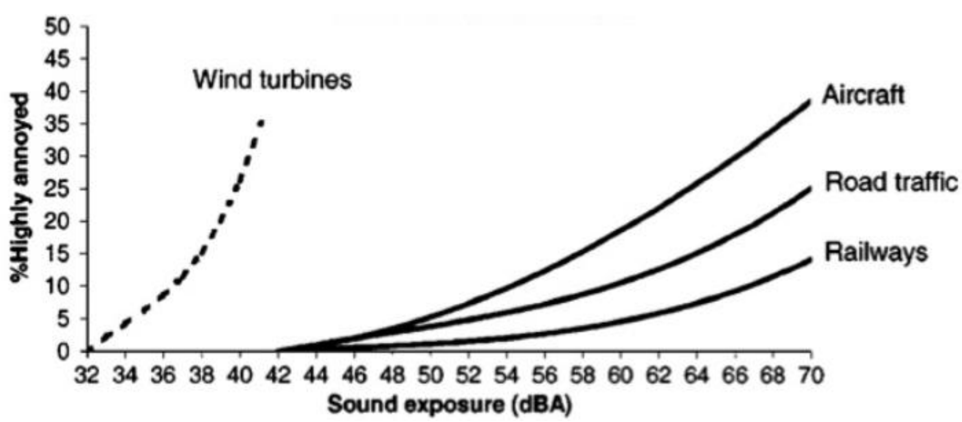
Propagation of sound is primarily a function of distance, but it can also be affected by the topography of the surrounding terrain, humidity and atmospheric conditions, wind speed, presence and type of surrounding structures, and roughness of the turbine blades. As a general rule, higher wind speeds cause a turbine to produce greater noise levels. At the same time, background noise can mask turbine sounds. For instance, noise produced by high winds, rustling of vegetation, traffic, and the sound of waves can cancel out turbine sound in some cases (Potty and Miller 2012; National Academy of Sciences 2007). Computer modeling that takes into account many of the site specific physical factors listed below can be used to create sound contour maps of the relative noise impacts to the area surrounding a proposed project. While modeling is often conducted to be conservative (or predict impacts under worst-case conditions), even small changes in the turbine's sound power level at the source due to inflow turbulence or wear and tear of the blades can cause changes in the propagation of noise to the surrounding area. Therefore, it is possible that some homes may experience at times higher noise levels than originally predicted (AEI, 2012; Moller and Pedersen, 2011).

Infrasound

The scientific literature on infrasonic and low-frequency noise from large wind turbines is very limited, as is research on the effects of infrasound from operating wind turbines on human health. The lower limit of the human hearing is around 20Hz, and the terms infrasound and infrasonic refer to frequencies below 20Hz. However, if the level is sufficiently high (above

90dB) humans may perceive infrasound and at levels above 140dB, infrasound has the ability to produce physical pain (MA DEP and DPH 2012). Below 20Hz, if audible the tonal sensation disappears, the sound becomes discontinuous in character, and a sensation of pressure at the eardrums may occur. The available research to date has found that upwind turbines (which are the most common type of wind turbine) the level of infrasound is much below the normal hearing threshold even close to the turbine (Bolin et al. 2011), especially for turbines less than 2MW (Møller and Pedersen, 2011). However, Salt and Kaltenbach (2011) assert that even in cases where infrasound cannot be heard, it may still have an impact on the human ear. The need for greater study, especially on exposure to infrasound over longer periods of has been suggested including Salt and Litchtenhan (2011) stating: "The complexity of the ear's response to infrasound leads us to the conclusion that there are many aspects that need to be better understood before the influence of wind turbine noise on the ear can be dismissed as insignificant."

Reported impacts of wind turbine noise on surrounding areas and neighbors at sites around the world have included annoyance, diminished quality of life, and sleep disruption. Although the noise from turbines is not physically different from noise produced by other industrial sources (Colby et al. 2009), Pedersen and Waye (2005) show evidence that people *perceive* wind turbine noise differently from other types of noise. Specifically, these authors found that people perceive wind turbine noise as more annoying than transportation or industrial noise at comparable levels. They suggest this may be due to the swishing quality of wind turbine noise, changes in noise throughout the 24-hour period, and the lack of night-time abatement (see Ch. 1 Figure 19; Ontario Chief Medical Officer of Health 2010).



Ch. 1 Figure 19. Annoyance associated with exposure to different environmental noises (Pedersen and Waye, 2004)

Likewise, the Acoustic Ecology Institute (2009, 2011, and 2012) found that several properties of wind turbine noise, including amplitude modulation, sound diversity (thumping, whistling, rumbling), high proportions of low-frequency noise, and lack of nighttime abatement, may explain why turbine noise is often perceived as problematic at seemingly low levels of sound. Amplitude modulation, or the pulsating loudness of the noise, is also cited as a source of annoyance (Colby *et al.* 2009; Minnesota Department of Health 2009; RERL 2006).

Moreover, annoyance is highly dependent on individual characteristics, both psychological (how one feels about the source of annoyance) and physiological (ability to perceive the stimuli, severity of any innate reaction to it). Perceptions of annoyance can be mediated by a variety of physical factors, including personal sensitivity, type and degree of background noise, and presence of acoustic effects other than broadband sound (such as amplitude modulation and pure tones). In addition, Pedersen and Waye (2004) found compelling evidence that the experience of annoyance resulting from hearing wind turbine noise is often correlated with sensations that are not acoustic in nature, such as:

- Visibility of wind turbines: Annoyance associated with wind turbine sound tends to be greater where people see wind turbines and perceive them as unattractive.
- Presence of shadow flicker: Turbine noise tends to be considered more annoying when experienced in combination with visual impacts such as shadow flicker.
- Attitudes towards wind turbines: Annoyance associated with wind turbine sound tends to be correlated with general opinions about the wind turbines and with attitudes towards the siting process.

All of these factors interact to determine each individual's perception of the acoustic impacts of wind turbines.

While some concerned parties have posited a relationship between turbine noise and health impacts, the National Academy of Sciences (2007) concluded that the balance of evidence fails to support a link between wind turbine noise and adverse health impacts. Supporting this finding, a recent medical review of the current understanding of the health impacts of prepared for the Massachusetts Department of Environmental Protection and Department of Public Health (MA DEP and MA DPH 2012) found a lack of medical research linking wind turbine noise to negative health effects. Specifically, the Massachusetts study found that:

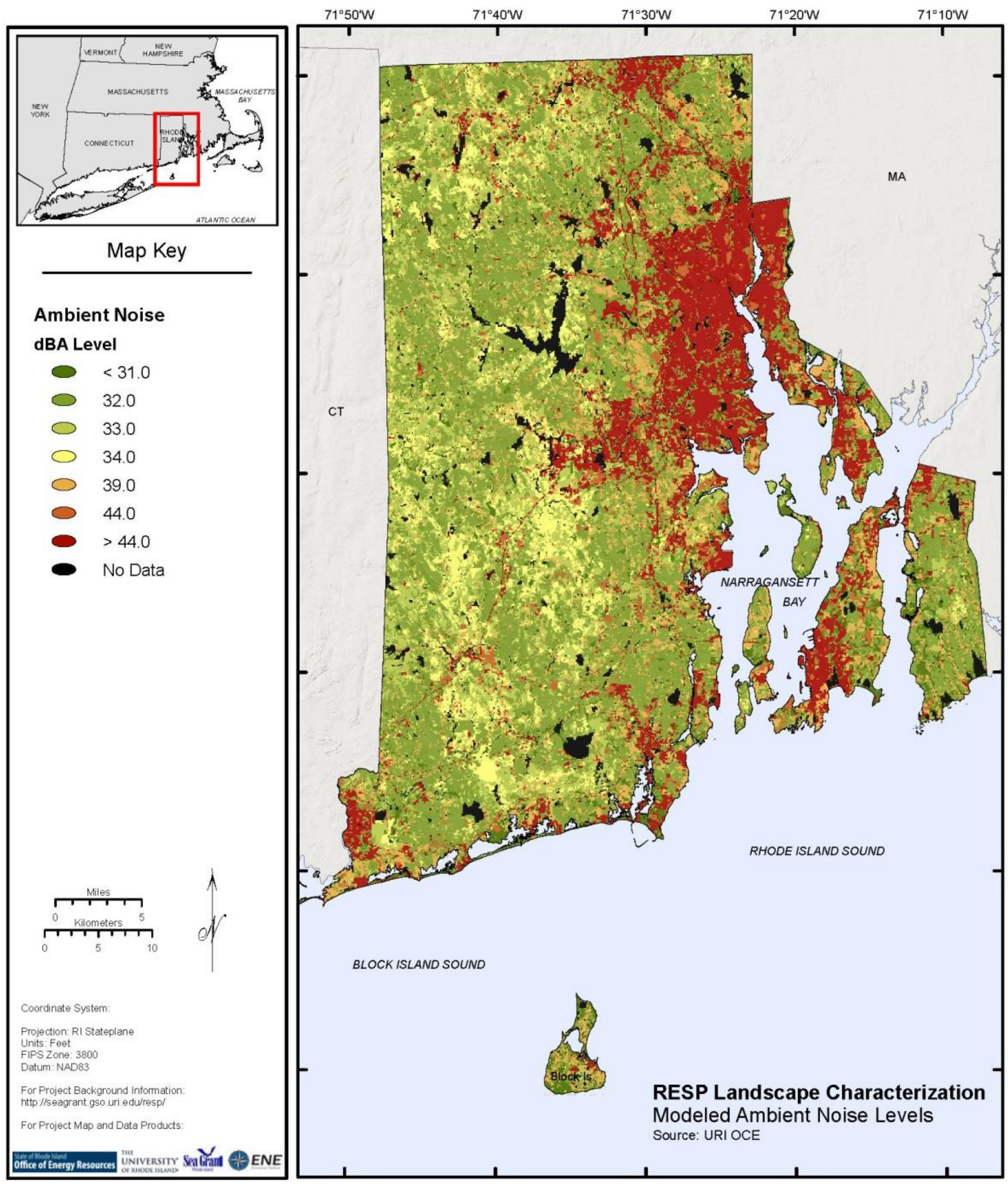
- Most medical literature on human response to wind turbines relates to self-reported "annoyance," and this response appears to be a function of some combination of the sound itself, reactions to the visual appearance of the turbine, and attitudes towards the wind turbine project in general.
- An association between noise from wind turbines and sleep disruption has not been medically documented despite the existence of several epidemiological studies on the topic. This is not to say that noise from some wind turbines does not cause sleep disruption.

- A very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest of sleepers at that same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study is needed to identify these levels.
- Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence from wind turbines, there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.
- There is insufficient evidence that the noise from wind turbines directly (i.e., independent from an effect on annoyance or sleep) causes health problems or disease.
- Claims that infrasound from wind turbines directly impacts the vestibular system (inner ear/sense of balance) have not been confirmed scientifically. Available evidence shows that the infrasound levels near wind turbines do not impact the vestibular system.
- There is no evidence for a set of health effects from exposure to wind turbine noise that could be characterized as a "Wind Turbine Syndrome."
- The weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.
  None of the limited medical evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

Additional reports directly referencing this topic, including those prepared by the state/provincial governments of Wisconsin (Roberts and Roberts 2010), Ohio (Ohio Deparment of Health 2008), Minnesota (Minnesota Department of Health 2009), and Ontario (Ontario Chief Medical Officer of Health 2010), as well as publications from the Acoustic Ecology Institute (2009, 2011, and 2012) and the French National Academy of Medicine (Chouard 2006) may also serve as useful resources on this topic.

Ambient noise levels are a key factor in shaping the perception of noise from wind turbines. As sound levels increase over ambient noise there is a greater chance of perception; as perception increases in a population, the chance of widespread annoyance also increases (Pedersen and Waye 2004). Because perception is a key aspect when assessing the potential impacts of wind turbine noise, assessing ambient noise levels can help predict the noise impacts of wind turbines are different sites. Ch. 1 Figure 20 maps the average background noise based on land use types in Rhode Island (Potty and Miller 2012). The ambient noise map is created using the land use information and mapping that information into approximate values of ambient noise. The ambient noise values corresponding to various land types such as open water, urban recreational grasses, low and high intensity residential area, commercial and industrial areas, forest land, grass land and wetland were obtained from reported values in literature (Baverstock *et al.* 1991; Gjestland 2008; Nilsson 2007). These estimated ambient values cannot substitute for actual ambient noise measurements taken at the actual location of a new or proposed wind turbine.

In addition to modeling ambient noise around Rhode Island, the RESP created a web-based tool to display project noise levels based on the proposed turbine specifications. This tool further assists in identifying the areas around a proposed wind turbine that will likely be affected by wind turbine noise. More information on this tool is available in Section 4.2 of this chapter and in Potty and Miller (2012) in Volume II of the RESP document.



Ch. 1 Figure 20. Modeled Ambient or Background Noise Levels Around Rhode Island (in dBA).

3.4 Shadow Flicker

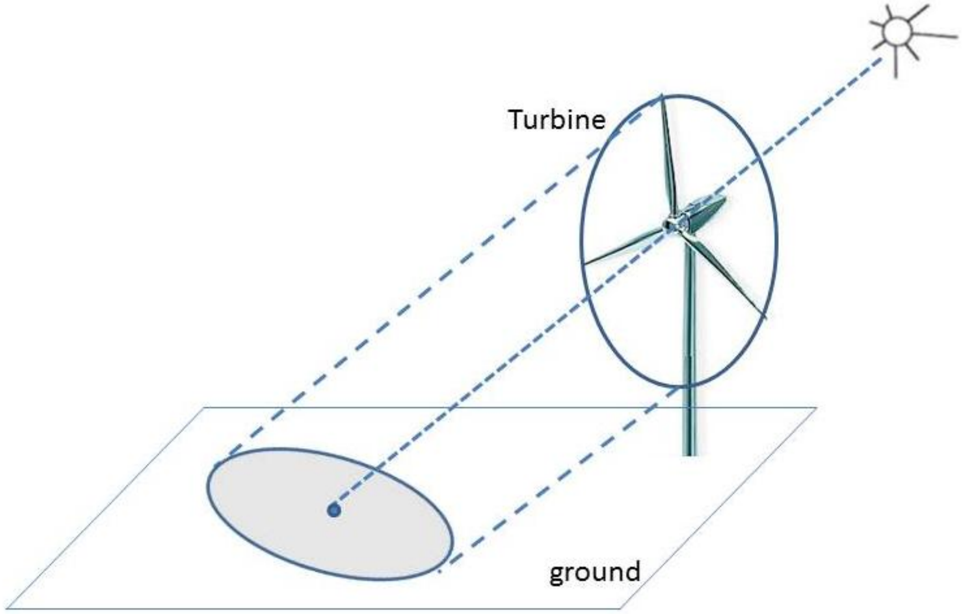
SECTION SUMMARY

- Moving wind turbine blades can cause a shadow flicker effect when positioned within the line of sight between the sun and a viewer.
- Given high enough exposure, shadow flicker can be considered annoying and can cause disruption to daily life. It does not, however, induce seizures, as had previously been hypothesized.
- Shadow flicker takes place only when the sun is shining and when the blades are facing the sun resulting in a shadow. In an average year in Rhode Island, slightly over half of the days each year are sunny or partly sunny.
- The shadow flicker effect is visible only at certain times of the day and the year, when the sun is at a low angle in the sky.
- The zone affected by shadow flicker can be predicted using computer models. Unobstructed shadows in our latitudes will typically have a bow tie or flattened cross shape.
- Predictive models can be used to establish setback zones to minimize impacts of shadow flicker on nearby residents.
- Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation (MA DEP and DPH, 2012).

Like other tall structures, wind turbines cast a shadow on the surrounding area when the sun is shining. These shadows are visible when the turbine blades are in the line of sight between an observer and the sun (see Ch. 1 Figure 21). In contrast to other tall structures, wind turbines have moving components. When turbine blades are turning during sunny days that produce shadows, a flickering effect may result. This phenomenon, called shadow flicker, can affect observers positioned within the shadow zone by causing annoyance and distraction (National Academy of Sciences 2007).

The existence and intensity of shadow flicker are affected by a number of factors (Potty and Miller 2012):

- Strength of the sunlight as affected by cloud cover;
- The location of the line of sight of the observer relative to the sun and the turbine. Line of sight is in turn dependent on the sun's height in the sky, which varies with latitude and longitude, time of day, and time of year;
- Distance between the observer and the turbine, which affects the distinctness of the shadows;
- Presence of obstructions such as buildings or vegetation;
- Orientation of the turbine, depending on wind conditions.



Ch. 1 Figure 21. Illustration of the Location of the Shadow Zone Relative to the Turbine and Sun.

The effect of the shadow flicker will be maximum when the rotor blades are perpendicular to the line between the sun and the viewer. For example, if the sun is shining but due to the direction of the wind the wind turbine is oriented so that the bladeas are are parallel to the line of sight between the sun and the viewer, shadow flicker may be minimal or completely eliminated. Shadow flicker is most pronounced in northern latitudes during winter months because of the lower angle of the sun in the winter sky (Potty *et al.* 2012). However, it is possible to encounter shadow flicker at any time of year, during brief periods after sunrise and before sunset. Rhode Island is sunny or partly sunny about half of the time (see Ch. 1 Table 5). Sunny days are defined as days when clouds cover 30% of less of the sky during daylight hours. Partly sunny days are defined as days when clouds cover 40-70% of the sky during the daytime (NOAA 2008).

Ch. 1 Table 5. Average Number of Days with Sunshine in Rhode Island (Source: NOAA 2008).

Location	**Clear**	**Partly Cloudy**	**Total days with sun**
Providence	98	103	201 (55%)
Block Island	98	113	211 (58%)

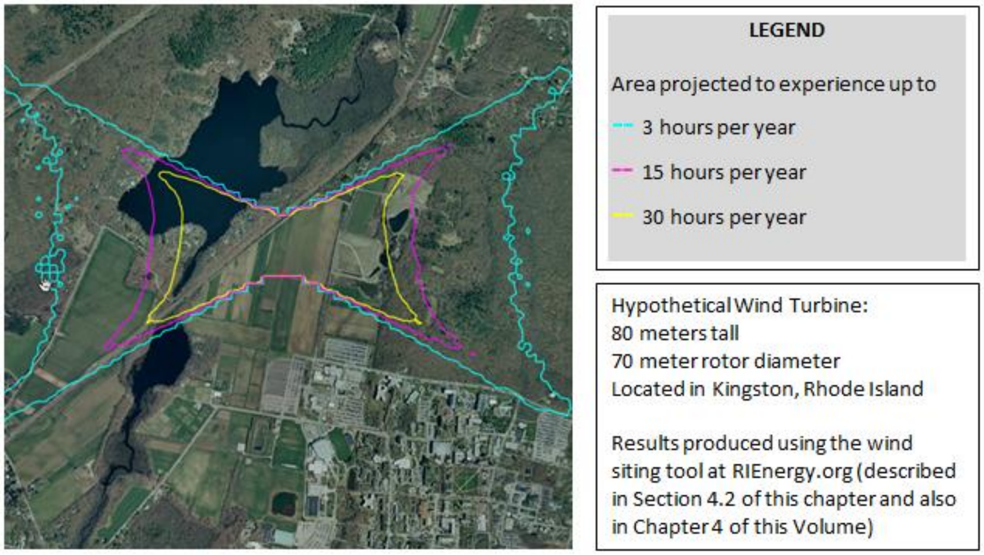
Shadows that are cast close to a turbine are more intense, distinct, and focused; as one moves further away, shadow intensity fades (Potty and Miller 2012). Several researchers have concluded that significant shadow flicker does not occur at distances greater than ten rotor diameters away from the turbine (UK Shadow Flicker Evidence Base, Department of Energy and Climate Change, Potty and Miller 2012). Elkinton and Wright (2007) report that German standards define flicker as occurring when the rotating blade of a turbine obscures at least 20% of the sun's orb in the sky. The amount of the sun's orb obscured by a rotating blade is a function of the distance between an observer and a turbine. For instance, for a blade measuring 2.5m (8.2ft) wide, an observer would have to be no more than 3,000ft (914m) away from the turbine for the sun's orb to appear 20% obscured by a turbine blade (Elkinton and Wright 2007). Thus, in this example, 3000ft (914m) would be the effective limit of noticeable flicker. According to this generalization, turbines with larger blades have a larger radius of shadow flicker, while turbines with smaller blades have a smaller radius of shadow flicker.

Finally, shadow flicker is a function of the presence of other objects or structures located between the turbine and the observer. For instance, shadows produced by wind turbines may be blocked or dissipated by buildings, hills, or trees. Evergreen trees can block shadows fairly consistently year-round, while deciduous trees tend to be less effective at blocking shadow flicker in the winter months when they are bare.

Shadow flicker impacts can be predicted prior to construction of a turbine through computer modeling. Shadow flicker models are highly accurate when accurate sun and wind vector data are available as inputs. Models can be used to predict shadow flicker outcomes in conditions ranging from moderate to "worst case" scenarios. In a "worst case" model, only the movement of the sun, topography, and the height and breadth of the turbine are considered. Limiting inputs to these factors produces maximum values for distance and degree of shadow flicker, and can contribute to very conservative setback designations. To model more realistic scenarios, wind direction, speed, obstructions, and historical cloud cover are also factored into the evaluation. Potty and Miller (2012) estimate that the results of factoring in these inputs can be as amount to as little as 18 percent of shadow flicker results based on sun, topography, and turbine size alone.

Both approaches (worst-case and moderate) can be used to produce contour maps and data sets showing maximum annual and daily levels of shadow flicker. Each approach is valuable for different purposes: worst case scenarios are most useful for screening a range of sites for a potential wind turbine, while more realistic calculations are useful in determining if a project will comply with municipal standards that cap the amount of shadow flicker at an acceptable level.

Ch. 1 Figure 22 provides an example worst-case scenario output from the RESP shadow flicker model. Due to the path of the sun and the associated azimuthal and elevations angle, typically, the area of land which may be affected by shadow flicker in our latitudes will be shaped like a bow tie or flattened cross when viewed from above (Potty and Miller 2012). Shadow flicker impacts can be understood by considering both the zone of impact and the hours per year that shadow flicker is predicted to occur within this zone. Parts of the zone will experience a greater number of hours of flicker than others. Potty and Miller (2012) describe the calculations associated with these models in greater detail in Volume II of the RESP report.



Ch. 1 Figure 22. Example of a Shadow Flicker Analysis using a Hypothetical Turbine. (The color scale indicates the total shadow duration in hours affecting the area adjacent to the wind turbine.)

Shadow Flicker Health Impacts and Annoyance

Neighbors of wind energy projects have in some cases reported that shadow flicker can be extremely annoying. When severe enough, it can interfere with daily life and lead to trouble concentrating (National Academy of Sciences 2007). In addition, some people report experiencing vertigo-like symptoms during episodes of shadow flicker exposure. In close proximity (800-1300 feet, or about 250-400 meters), households have reported that shadow flicker has interfered in their daily lives (Bittner-Mackin, E. 2006). The National Academy of Science (2007) writes: “Shadow flicker can be a nuisance to people living near a wind-energy project. It is sometimes difficult to work in a dwelling if there is shadow flicker on a window” (161). The level of annoyance resulting from shadow flicker varies between individuals; however reports show that in the worst cases, it can be a significant detractor from quality of life, causing a feeling of loss of privacy and lack of control, in addition to annoyance (Pedersen *et al.* 2007).[4]

At one point, there was concern that shadow flicker might have the capacity to induce seizures. However, the National Academy of Sciences (2007), the Epilepsy Foundation, and several other bodies have concluded that shadows caused by turbine blades do not flicker quickly enough to induce seizures. The flicker frequency that provokes seizures in photosensitive

[4] Based off a study where 15 participants were interviewed. All participants lived in detached houses in a small rural district (25,000 inhabitants) in the south of Sweden. In the flat agricultural landscape, 44 wind turbines were operating. Most of them were placed as single objects and not in groups, which gave a scattered impression. All of the participants lived within 600 meters of a wind turbine and could see more than one wind turbine from their dwelling, often in several directions.

individuals is 5-30Hz, well above the maximum for wind turbines, which is generally between 0.5 and 1.1Hz for a turbine of typical commercial size (MA DEP and DPH, 2012). No direct physiological health impacts have been found to result from shadow flicker (Erba 2012).

3.5 Electromagnetic Interference

SECTION SUMMARY

- Like other tall structures, wind turbines have the potential to interfere with electromagnetic waves, such as those used by television, cell phones, radio, and scanning telemetry systems.
- Turbines can cause both blocking and reflection of these signals when located in the line of site between transmitter and receiver.
- Electromagnetic occurrence is less of an issue with newer wind turbines that are not made of metal.
- Appropriate siting of wind turbines to avoid installations in the sight lines of affected technologies will minimize any impacts.

Wind turbines, like other tall structures, have the potential to interfere with devices and equipment that use line-of-sight wavelength-based communications. Electromagnetic interference (EMI) occurs when an object positioned between a transmitter and a receiver of electromagnetic radiation signals passively obstructs, reflects, or refracts these signals. This category includes television, radio, cellular phone devices, and fixed radio links. If wind turbines are erected along the pathways traveled by these signals, they can degrade their performance.

Telecommunications impacts were a larger problem in the past, when wind turbine blades were made primarily of metal. Now that most blade parts are made of synthetic materials (with metallic components used only for de-icing workings, monitoring systems, and other small parts) the potential for interference has been greatly reduced (Haviaropolous 2011).

Wind turbines are capable of causing two primary types of interference:

Signal Blocking This occurs when a wind turbine blocks the reception of a signal for some distance behind the turbine, creating a shadow zone where no signal can reach a receiver. A turbine can also deflect or weaken a signal. The size of the shadow zone is directly related to the materials used in the construction of the turbine and the height and breadth of the turbine (Ofcom 2009).

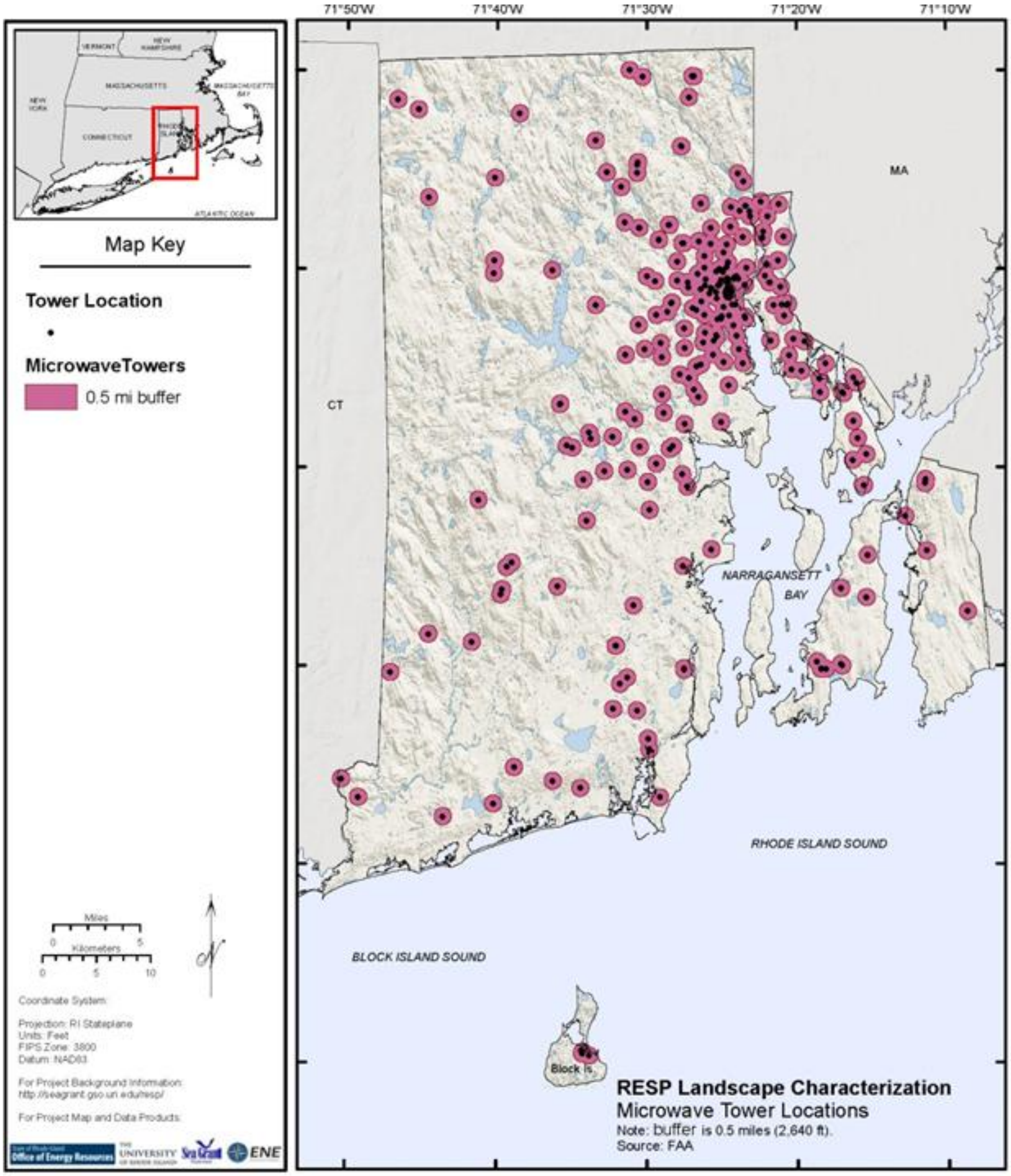
Signal Reflection All structures within line of sight to a transmitter reflect signals to varying degrees. The type and magnitude of reflection are dependent on the size, motion, and material composition of the structure. In the case of wind turbines, the rotational speed, composition, height, breadth, and the angle of the blades relative to the transmitter are key factors in determining reflection effects (Ofcom 2009).

Ch. 1 Table 6 summarizes the potential interference effects that wind turbines may cause to television, radio or cellular phones.

Ch. 1 Table 6. Potential Interference Effects Caused by Wind Turbines.

Television	Wind turbines affect television signals only when positioned in the line of site between residential television receivers and the transmitter. The impact is known as 'ghosting', wherein a distorted and delayed signal arrives at a receiver after the main signal, causing a secondary image to overlap with the primary image on the screen. The British Office of Communications suggests that digital television sets are less susceptible to reflective signals than analog sets (Sustainable Development Commission 2005)
Satellite Television	Reflection disrupts satellite television only when a structure is erected within the line of sight between a residential television receiver and a satellite transmitter. Because of the high angle of incoming satellite signals relative the Earth, only receivers positioned very close to the base of a turbine are likely to experience interference; such situations are extremely rare (Ofcom 2009).
Cellular Phones	The Massachusetts Technology Collaborative (2006), in a review of a proposed turbine measuring over 380ft (116m) high located 380ft (116m) from a cellular tower in North Eastham, described the possible effects on cell phone coverage: • Electromagnetic interference: Wind Turbines have not been reported to be significant emitters of EMI. The electric motors and generators used in the nacelle of a wind turbine emit a small amount of low frequency electromagnetic noise. Because this noise is outside of the high frequency band used by cellular telephones, it should not cause system interference. • Near-field effects: Antennas that transmit and receive a signal have a “near-field” zone. For the antennas to work, no object that can conduct or absorb radio waves may be present in this zone. The near-field zone for Ultra High Frequency (UHF) signals, such as cellular telephones (800MHz to 1900MHz) is approximately 20 meters (70 feet). • Diffraction: Diffraction is a phenomenon that occurs when a wind turbine partially or totally blocks a radio wave. It may result in a loss of signal strength, but does not eliminate the signal entirely. Diffraction effects from wind turbines can be avoided by placing them outside the first Fresnel Zone, which determines the range in which signal loss is experienced. • Reflection/scattering: Scattering occurs when waves are scattered after bouncing off an object that has reflective properties. Because the tower and blades of a wind turbine are relatively slim and curved, they tend to scatter rather than obstruct most waves. Furthermore, modern blades are made from glass-reinforced plastic, a material that is essentially transparent to electromagnetic waves.
FM & DBA Radio	Wind turbines can cause hissing or signal distortion of FM and DBA radio in very close ranges. This effect is mostly limited to older turbines; it is rare for new turbines to impact radio broadcasts. Turbines would possibly interfere with FM & DBA broadcasts only within a few ten meters of the turbine (Ofcom 2009)
Scanning Telemetry Systems	Water and power industries use scanning telemetry systems to monitor and control substations, water and sewage works, pipelines and supply networks. These systems work in the UHF band and transmit over a wider zone and are therefore more vulnerable to multi-path effects from reflecting objects such as wind turbines. Consequently, the requested clearance zones may be large, on the order of hundreds of meters or more (Ofcom 2009).
Fixed Radio Links	Many public safety radio systems rely on fixed radio links. Wind turbines, when placed within the line of sight between a receiver and transponder, can have a negative effect on fixed radio links, especially those using microwave wavelengths and frequencies in the gigahertz range. The capacity of a wind turbine to degrade public safety communications presents a potentially serious safety threat (Sustainable Development Commission 2005).

The simplest way to avoid potential EMI effects of wind turbines is to site wind turbines out of the line of site between a receiver and a transmitter of communication signals that are potentially affected. Ch. 1 Figure 23 shows the locations of microwave communications towers throughout Rhode Island, with a 0.5 mile (0.8km) buffer around each one representing areas where interference effects should be considered closely. It should be possible to avoid major EMI impacts by taking care when siting wind turbines near these locations.



Ch. 1 Figure 23. Communication Tower Locations with a 0.5 mile (0.8km) buffer.

3.6 Avian and Bat Impacts

SECTION SUMMARY

- Wind turbines can affect birds and bats by causing collisions, displacement, barrier effects, and habitat loss.
- Compared to other anthropogenic sources such as buildings, power lines and automobiles, bird collisions with wind turbines are relatively low.
- Bats can also suffer from barotrauma, a form of internal tissue damage that occurs when bats experience a sudden drop in pressure when flying behind a spinning turbine rotor.
- The likelihood of collision between birds or bats and wind turbines varies as a function of species abundance, species behavior, season, location, and turbine characteristics.
- Most bird mortalities resulting from collision with wind turbines occur during spring and fall migrations. Most bat mortalities occur from mid-summer to fall.
- Construction of turbines in important bird or bat habitat can cause habitat fragmenting and/or lead to avoidance behavior.
- The four main habitat types used by birds in Rhode Island are grasslands, scrub-shrub, forests, and coasts. Some habitats are more important and/or vulnerable that others; each may require a different form of protection when siting wind turbines
- Vulnerable species may represent a priority concern when siting wind turbines. Rhode Island has two federally listed threatened bird species and one federally listed endangered bat species. In addition, 53 bird species are listed as endangered, threatened, or of concern by the state.
- Establishing buffers around known nests and/or key habitats used by vulnerable species may be necessary to protect these species from the effects of wind turbines.

The potential for wind turbines to have impacts on birds and bats is often one main environmental concern in debates over wind energy development. Recognizing the importance of this potential environmental impact, RESP research synthesized what is currently known about the impacts to birds and bats from wind turbines and compiled an exhaustive collection of existing data on the occurrence and distribution of bird and bat species on Rhode Island. This section provides a brief summary of the findings of RESP researchers Paton *et al*. (2012); the researchers' full technical report is available in Volume II.

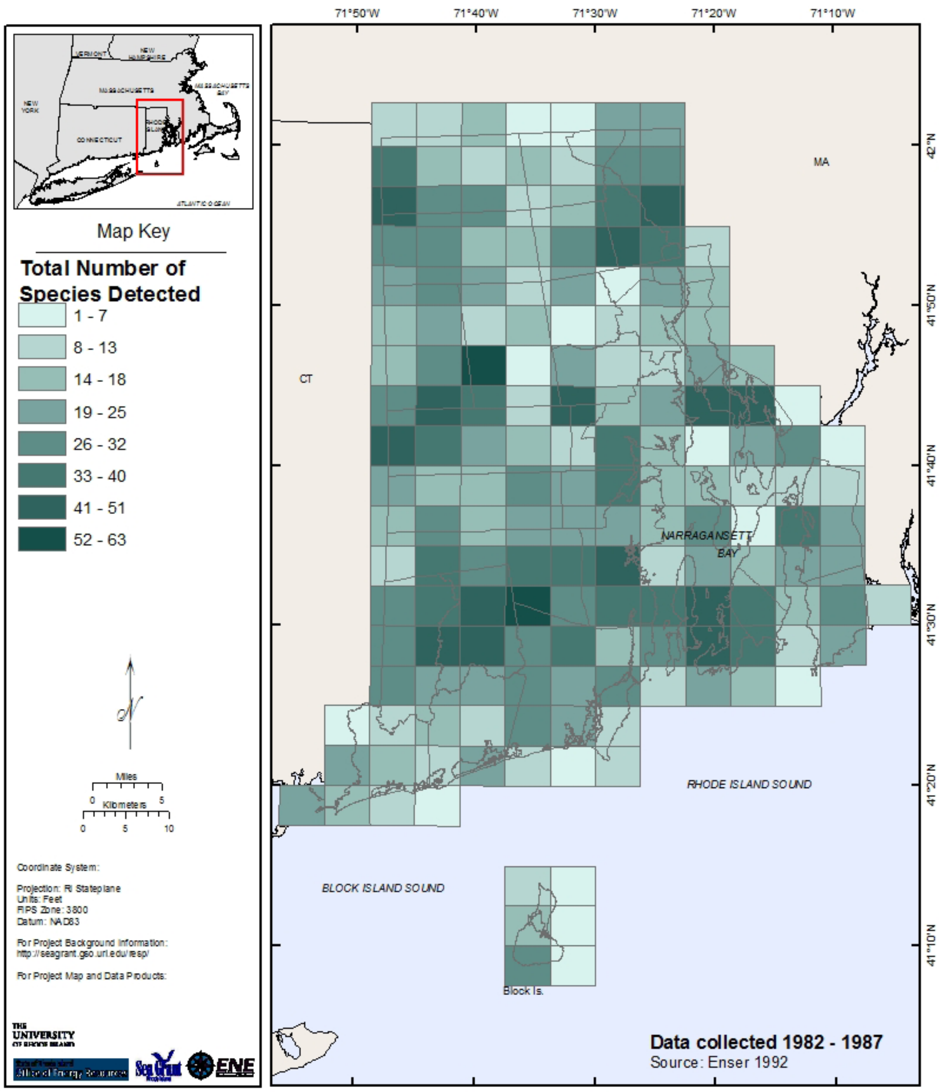
Species Distribution and Habitat

A very rough indication of bird utilization of different areas around Rhode Island is given in

Ch. 1 Figure 24, which depicts the concentration of breeding populations of birds throughout the state. While this map offers a rough sense of bird distribution around the state, it is not exhaustive, as migratory stopover points can be just as vital as breeding locations for the maintenance of resilient bird populations. Furthermore, areas utilized by birds must be considered within the larger context of each species' general wellbeing and habitat usage, both within and outside of Rhode Island.

When weighing the potential impacts of wind turbine construction on birds and bats in an area, highest priority must be given to those areas used by species listed as endangered or threatened. In Rhode Island, two bird species and one bat species are federally listed as endangered or threatened, and 53 bird species are listed as endangered, threatened, or of concern by the state (see Ch. 1 Table 7).

> There are 388 bird species (Desante and Pyle 1986; August *et al.* 2001) and 9 bat species (August *et al.* 2001; Smith and McWilliams 2011) documented in Rhode Island. These numbers include both breeding (166 bird species and four bat species) and visiting (222 bird species and five bat species) populations. Of the bird species with a record of breeding in Rhode Island, 56 are common, 10 are fairly common, 56 are uncommon, and 47 are rare. Of the bird species with a record of migrating through Rhode Island in summer months, 5 are common, 6 are uncommon, 32 are rare, and 8 are accidental.



Ch. 1 Figure 24. Density of Breeding Bird Species in Rhode Island Based on Surveys Conducted from 1982 – 1987 (Enser 1992). Shown is the total number of species of birds with a confirmed nest in each grid cell (25 km2), thus this figure represents spatial variation in breeding bird species richness throughout Rhode Island.

Ch. 1 Table 7. Bird Species with Protected Status in Rhode Island.

Common name	Scientific name	Status	Areas of importance
Roseate Tern	*Sterna dougallii*	FT	Nearshore, shallow waters in western RI (e.g., Little Narragansett Bay)
Piping Plover	*Charadrius melodus*	FT	Beaches in southern RI and Block Island
Bald Eagle	*Haliaeetus leucocephalus*	BGEPA	Scituate Reservoir (one nest in RI)
Pied-billed Grebe	*Podilymbus podiceps*	SE	Coastal ponds in southern RI
American Bittern	*Botaurus lentiginosus*	SE	Large stands of emergent vegetation near coastal ponds
Northern Harrier	*Circus cyaneus*	SE	Grasslands and shrublands of coastal southern RI and Block Island
Peregrine Falcon	*Falco peregrines*	SE	Providence, Mt. Hope Bridge, Newport Bridge, southern coast, Block Island
Upland Sandpiper	*Bartramia longicauda*	SE	Turf fields in South County
Barn Owl	*Tyto alba*	SE	Coastal grasslands, bluffs on Block Island and Trustom Pond
Cerulean Warbler	*Setophaga cerulean*	SE	Large contiguous forest habitat (currently very rare in RI)
Yellow-Breasted Chat	*Icteria virens*	SE	Shrub habitat (currently very rare in RI)
Least Bittern	*Ixobrychus exilis*	ST	Coastal ponds with emergent vegetation
Least Tern	*Sterna antillarum*	ST	Coastal beaches, salt ponds, and nearshore marine waters
Northern Parula	*Setophaga americana*	ST	Mature forests with epiphytic moss (3-5 known breeding locations in RI)
Black-Throated Blue Warbler	*Setophaga caerulescens*	ST	Coniferous forests (3-5 known breeding locations in RI)
Blackburnian Warbler	*Setophaga fusca*	ST	Coniferous forests (less than 5 known nesting locations in RI)
Grasshopper Sparrow	*Ammodramus savannarum*	ST	Grasslands with short bunch grasses (less than 5 known nesting locations in RI)
American Oystercatcher	*Haematopus palliates*	SC	Islands and peninsulas in Narragansett Bay and Little Narragansett Bay (rare migrant)
Osprey	*Pandion haliaetus*	SC	104 nests in RI

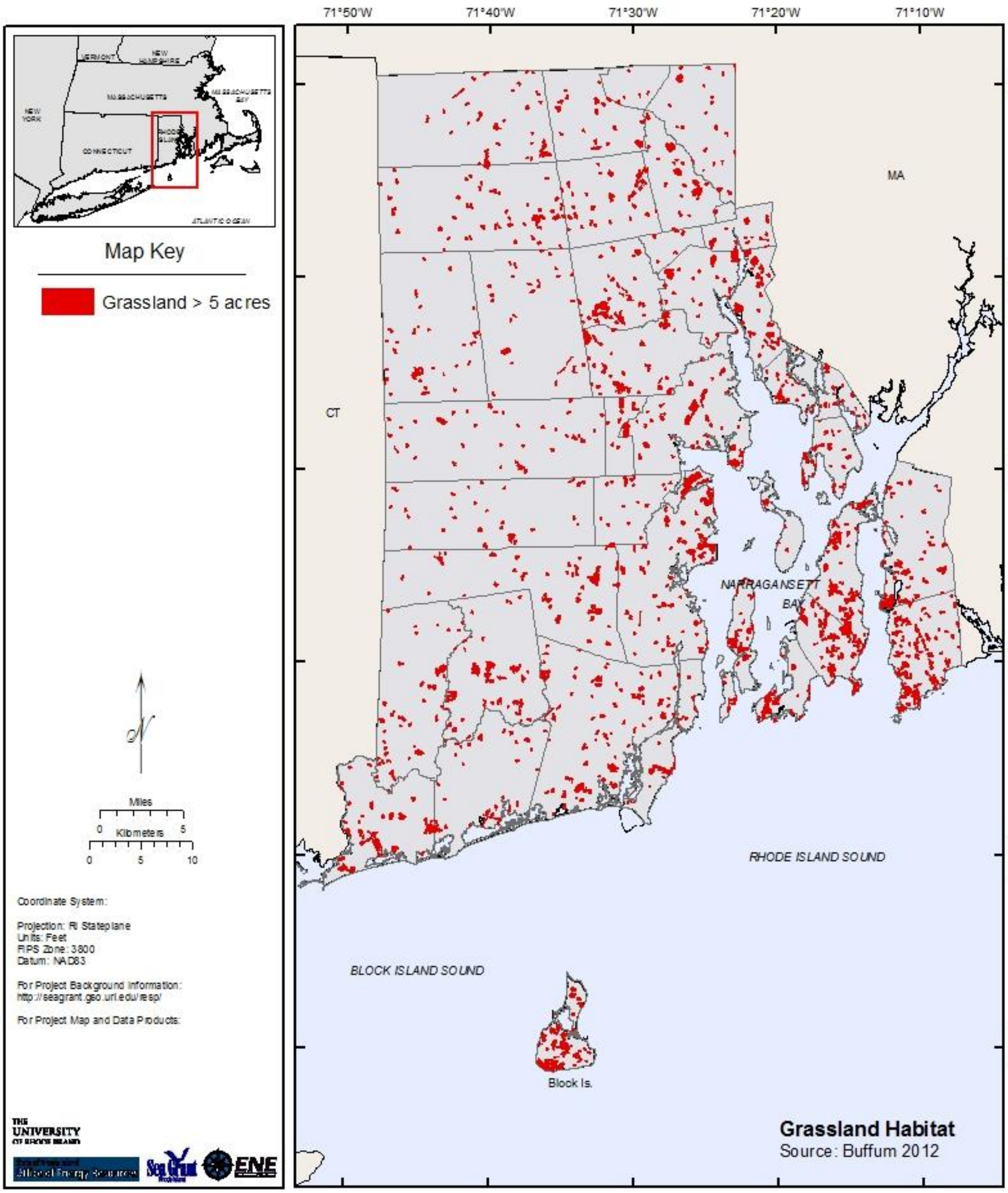
[FT = Federally Threatened (listed as threatened under the Endangered Species Act); BGEPA: Protected under the federal Bald and Golden Eagle Protection Act; SE = State Endangered (listed as endangered by DEM's Rhode Island Natural Heritage Program); ST = State Threatened (listed as threatened by DEM's Rhode Island Natural Heritage Program); SC = State species of concern (listed as a species of concern by DEM's Rhode Island Natural Heritage Program)]

Compared to birds, little is known about bat species in the state. One federally listed bat species, the Indiana bat (*Myotis sodalis*), occurs in Rhode Island. This species is classified as endangered due to declines in populations caused by human disturbance at nesting caves. However, studies of wind turbines suggest that turbines are not as detrimental to cave-roosting bat species as they are to tree-roosting species (Arnett *et al.* 2008). There are no known large cave-roosting populations of bats in Rhode Island (S. Paton, USFWS, personal communication). Tree-roosting bat species with established breeding sites in Rhode Island include the Little Brown Bat (*Myotis lucifugus*), the Northern Long-eared Bat (*Myotis septentrionalis*), the Tri-colored Bat (*Pipistrellus subflavus*), the Big Brown Bat (*Eptesicus fuscus*), and the Eastern Red Bat (*Lasiurus borealis*) (August *et al.* 2001). In addition, the Hoary Bat (*Lasiurus cinereus*), the Silver-haired Bat (*Lasionycteris noctivagans*), and the Eastern Small-footed Bat (*Myotis leibii*) have been detected as migrants in the state (Smith and McWilliams 2011).

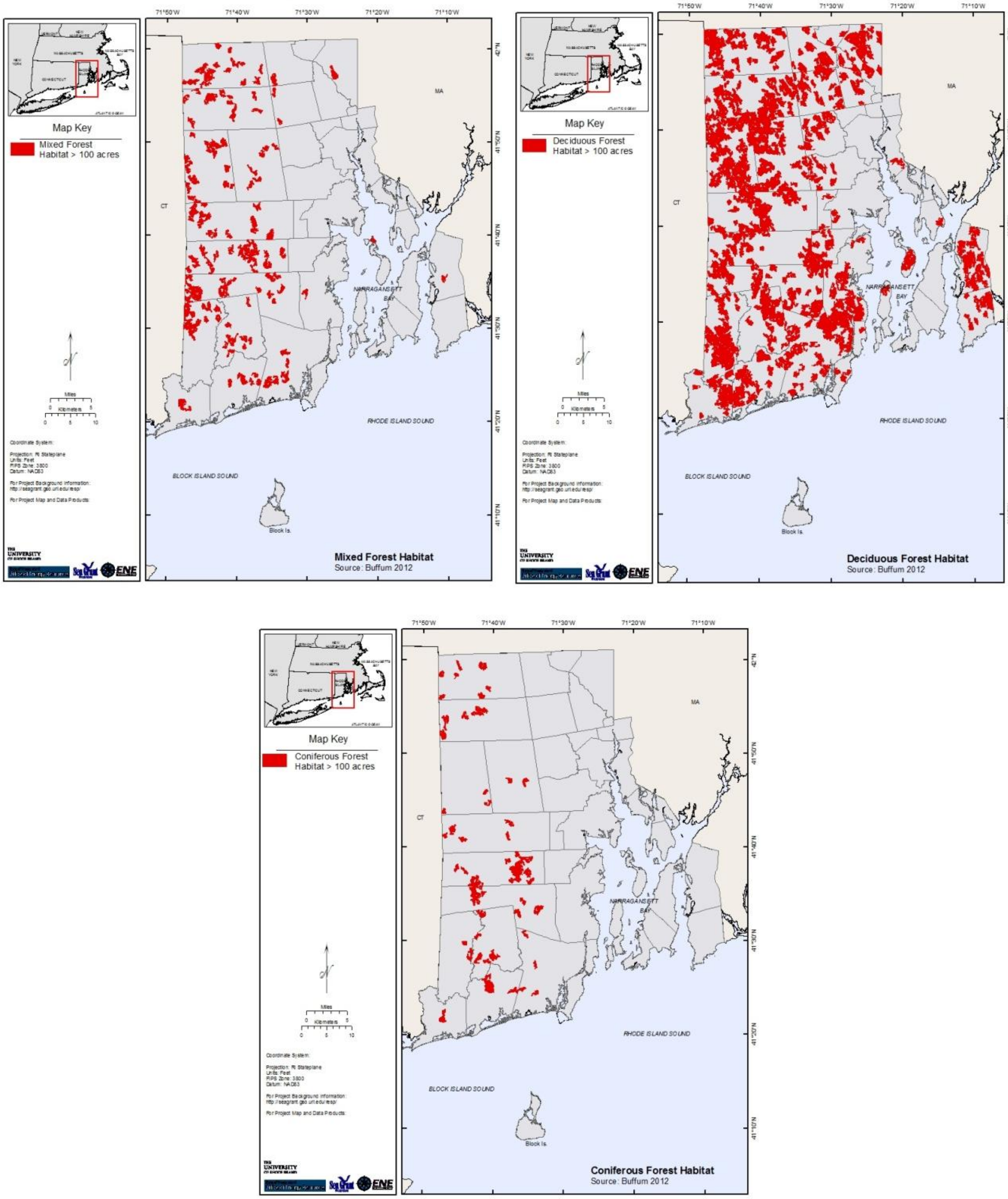
Habitat availability is one of the most important factors limiting bird populations (Newton 1998). The four main habitat types used by birds in Rhode Island – grasslands, scrub-shrub, forests, and coasts – may each be vulnerable to wind turbines in different ways, and each habitat type requires a tailored approach when siting wind turbines nearby. Ch. 1 Table 8 shows the number of species known to use each habitat type and Ch 1. Figures 25, 26, and 27 map the locations of these habitat types. More information is available in Paton *et al.* (2012) in Volume II.

Ch. 1 Table 8. Number of Bird Species by Habitat Type.

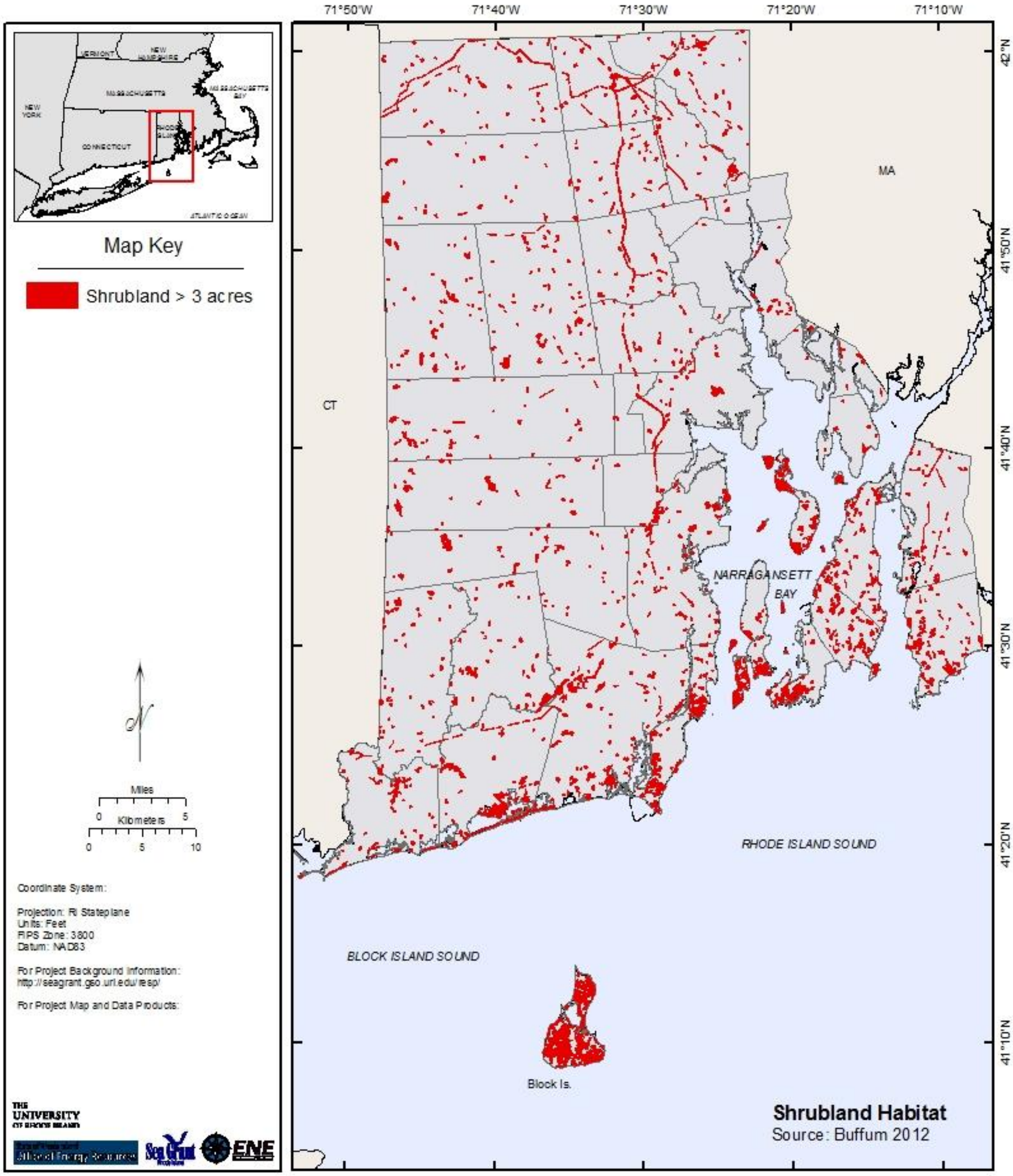
Habitat type	**# of Species**
Grassland	22 species
Scrub-shrub	36 species (including two state endangered and one state species of concern)
Forests	75 species (including one state endangered, one state threatened, and one state species of concern)
Coasts	78 shorebirds, 13 wading birds, and many more using coastal ponds. (Two are ST, four are state listed)



Ch. 1 Figure 25. Potential Grassland Habitat in Rhode Island.



Ch. 1 Figure 26. Rhode Island Forest Habitat.



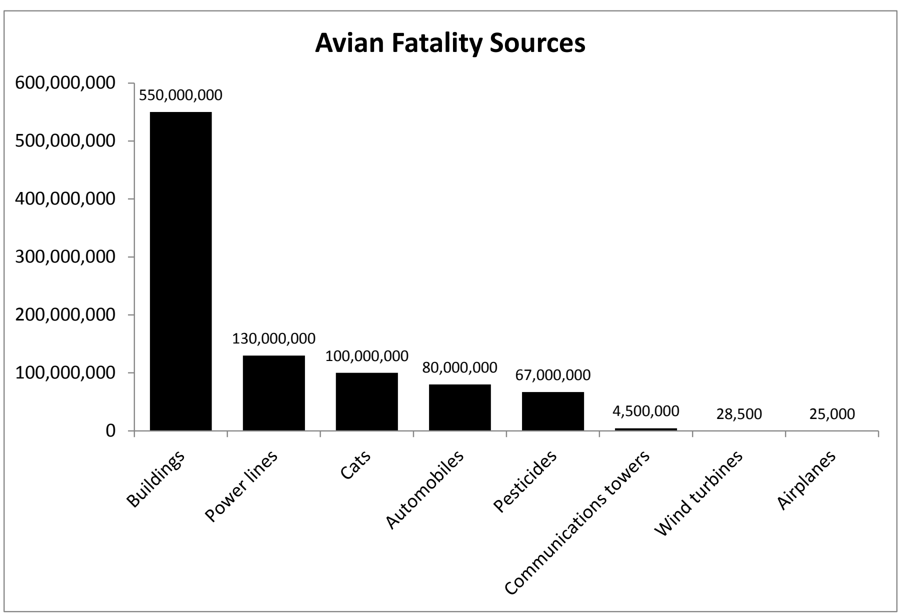
Ch. 1 Figure 27**. Rhode Island Shrubland Habitat.**

Potential Impacts from Wind Energy Development

Potential impacts of terrestrial wind turbines on birds and bats can be separated into four general categories: 1) collision risk, 2) displacement, 3) barrier effects, and 4) habitat loss (Drewitt and Langston 2006). Collisions can occur against rotors, towers, and associated transmission lines and guy wires (Drewitt and Langston 2006, 2008). Habitat loss occurs when wind power projects are erected in areas that birds or bats customarily use for breeding, wintering, foraging, or resting along migration routes. In some cases, valuable habitat (such as trees) is eliminated completely when a wind energy facility is erected; in other cases, the habitat persists but the presence of wind turbines deters birds or bats from using the area. This latter type is called a “barrier effect” (U.S.FWS 2012). For bats, an additional impact associated with turbines is barotrauma, defined as the internal tissue damage that can occur when bats suddenly encounter low pressure areas caused by rotating blades (Baerwald et al. 2008).

Collision

Collision fatalities are the most widely documented cause of bird and bat fatalities resulting from wind turbines (Paton *et al.* 2012). Paton et al. (2012) reviewed worldwide studies of bird-turbine collisions, and found that terrestrial wind facilities average 2.9 collision bird deaths per turbine per year. These collisions were found to result in 0-12.7 deaths per turbine per year. It should be noted that these rates are low relative to other anthropogenic sources of bird mortality, including transmission wires, vehicles, and other buildings/structures (Erickson et al 2001; Erickson et al 2005; see Ch. 1 Figure 28).



Ch. 1 Figure 28. Estimated number of birds killed annually in the United States from various anthropogenic sources based on Erickson et al. (2005).

In general, bats experience much higher rates of collision against wind turbines than birds. In a review of six studies from the eastern U.S., Paton *et al.* (2012) found that 80% of total collision mortalities related to wind turbines involved bats. A review of worldwide studies of bat collisions with wind turbines found that an average terrestrial wind turbine produces 8.4 bat collisions per year, causing 0-63.9 deaths per year.

While collision between a bird or bat and a wind turbine is a chance occurrence, collision probability is not entirely random. The likelihood of collision between birds or bats and wind turbines has been shown to vary as a function of species, season, location, and turbine characteristics. Ch. 1 Table 9 provides a summary of these factors.

Ch. 1 Table 9. Factors mediating impacts of wind turbines on birds and bats.

Factor	Relationship (all other things being equal)	References
Species abundance	More abundant species appear to make up a higher percentage of collision mortalities.	Kuvlesky *et al.* 2007
Species behavior	Some species appear to be attracted to turbines.	NRC 2007
Familiarity with the area	Resident species appear to be less prone to collision than migrating species.	Kingsley and Whittam 2005
Season	Most bird collisions occur during spring and fall migrations; most bat collisions occur during mid-summer to early fall migrations.	Mabee *et al.* 2005; Kingsley and Whittam 2005; Arnett *et al.* 2008, Brinkman 2006
Habitat	Birds and bats may be more prone to collision with turbines located in attractive habitat patches.	Paton *et al.* 2012
Proximity to migration routes	Birds and bats may be more likely to collide with wind turbines located along migration routes.	Paton *et al.* 2012
Facility size	Larger wind energy facilities with more turbines appear to lead to more bird and bat deaths than smaller facilities.	Kingsley and Whittam 2005
Turbine lighting	Turbine lighting appears to increase bird mortality by attracting nocturnal species.	Saidur 2011; Kingsley and Whittam 2005; Johnson *et al.* 2002).
Turbine height	For bats, taller turbines appear to be linked with higher mortalities. There is little relationship between mortality and turbine height for birds.	Paton *et al.* 2012; Arnett *et al.* 2008; Barclay *et al.* 2007
Blade speed	Birds tend to be more vulnerable to collision when blades are moving faster; bats tend to be more vulnerable to collision when blades are moving slower.	Kingsley and Whittam 2005; Arnett *et al.* 2008

<u>*Barotrauma in bats*</u>

In addition to direct collisions causing mortality in bats, barotrauma, or the rapid changes in air pressure causing internal tissue damage, could be a significant cause of mortality in some species (Baerwald *et al*. 2008). Researchers in Alberta, Canada, found 90% of turbine-related fatalities had evidence of injuries related to barotrauma, and over half of the deaths were likely caused by barotrauma (Baerwald et al. 2008). Barotrauma is not a significant source of fatality in birds, because they have smaller hearts and more rigid lungs than bats. The greater effect of barotrauma on bats may contribute to higher mortality rates of bats at many wind facilities (Baerwald *et al.* 2008).

<u>*Habitat Alteration*</u>

In addition to causing collision, wind turbines may lead to habitat loss, habitat fragmentation, and increases in edge effects for birds and bats (National Research Council 2007). In Europe, habitat loss is considered to be a greater risk for bird mortality than direct collisions (Kuvlesky *et al.* 2007). Studies have shown species abundances were lower in areas with wind turbines than in adjacent areas with no turbines in similar habitats (Osborn *et al.* 1998, Leddy *et al*. 1999, Pearce-Higgins *et al*. 2009), and that some species directly avoid wind farm areas by maintaining a certain distance around turbines. Madsen and Boertmann (2008) found that Pink-footed Geese (*Anser brachyrhynchus*) stayed approximately 200 m (656 ft) away from an active wind facility in Denmark. This response is likely to be species- and habitat-specific, as some studies show that turbines have little or no effect on bird abundances near wind turbines as compared to reference areas (Howe *et al*. 2002, Devereux *et al*. 2008). In some cases, habitats may not be destroyed but may significantly change. For example, if a forested habitat is converted to a grassland habitat during wind facility development (National Research Council 2007), a change in species composition could result.

The effect of wind turbines on bat habitat is also likely to be species- and habitat-specific, although very few studies directly assess this potential impact (National Research Council 2007; Cryan and Brown 2007). Alteration of the landscape to install wind turbines could potentially influence bat roosting sites and prey abundances, although the degree to which this may happen is largely unknown in most habitats and for most bat species in North America (National Research Council 2007). Horn *et al.* (2008) predicted that the increase in forest edges surrounding wind turbines could lead to increases in insect densities, which they found were positively related to bat activity near wind turbines. In one European study, bats were more abundant in reference areas without wind turbines than in comparable areas with wind turbines (Brinkmann and Schauer-Weisshahn 2006). It is unclear if this difference stems from habitat preference of from bats avoiding turbines.

Impact assessment and siting implications

Since bird and bat species are susceptible to wind turbine impacts in different ways, and since not all populations are equally vulnerable, a consideration of the effects of wind turbines on birds and bats in the state must be informed by analysis of species' life histories and population dynamics. Furthermore, different geographical areas within the state vary in their level of importance to different bird and bat species. When contemplating potential effects of a proposed turbine on birds and bats, it is important to consider the mix of species that occurs at a proposed site, the population status of each species in that mix, and the precise role that the proposed site plays in maintaining these populations. Based on information about bird and bat habitat, life histories, and population status, Paton *et al*. (2012) recommend several preventative measures to avoid impacts of wind turbines on bird and bat populations in Rhode Island. These recommendations are summarized in **Ch. 1 Table 10**. More information is available in Paton *et al.* (2012) in Volume II of this report.

Ch. 1 Table 10. Suggested Siting Considerations and Distances from the nests of sensitive species of birds and sensitive habitats in Rhode Island.

Species	Distance	Conservation status	Comments	Towns where documented
Bald Eagle	1 mile (1.6 km)	Protected under the Bald and Golden Eagle Act	Based on USFWS interpretation of the Bald and Golden Eagle Act	currently 1 known nest at Scituate Reservoir
Piping Plover	1 km	FT	Prevent impacts on coastal nesting beaches, foraging sites, and staging areas	South Kingstown, Narragansett, New Shoreham, Charlestown, Westerly, Middletown, Little Compton
Roseate Tern	1 km	FE	Prevent impacts roosting and staging areas	Westerly, Charlestown, South Kingstown, Middletown, Little Compton
Peregrine Falcon	0.5 km	SE	Avoid known nesting locations and concentration sites	New Shoreham, Westerly, Charlestown, South Kingstown, Newport, Providence
Osprey	0.5 km	SC	Known nesting locations	State-wide
American Oystercatcher	0.5 km	SC	Prevent impacts on coastal nesting beaches, foraging sites, and staging areas	Westerly, New Shoreham, Jamestown, Portsmouth, Tiverton, Newport, Bristol, Little Compton, Middletown, Warwick

Species	Distance	Conservation status	Comments	Towns where documented
Upland Sandpiper	0.1 km	SE	Avoid turf fields over 40 acres	Richmond, South Kingstown, North Kingstown
Least Tern	1 km	ST	Prevent impacts on coastal nesting beaches, foraging sites, and staging areas	Westerly, Charlestown, South Kingstown, Narragansett
Habitat Considerations				
Coastal ponds	1 km	Variety	Key nesting, foraging, and wintering habitat for a broad suite of species (e.g. Pied-billed Grebe; American Bittern; Least Bittern	Westerly, Charlestown, South Kingstown, Narragansett, Little Compton
National Wildlife Refuges	1 km	Variety	May contain critical habitats and listed species	Westerly, Charlestown, South Kingstown, Middletown, New Shoreham, Narragansett
State, Town and non-government Conservation Areas	0.1-1 km	Variety	Buffer distance to be coordinated with manager of conservation land	State-wide
Forest birds	0.1 km	Variety	Recommend not constructing within contiguous forests >100 acres, but turbines can be at the edge of large forest patches. Important habitat for Northern Parula, Black-throated Blue Warbler, Blackburnian Warbler, Cerulean Warbler	State-wide
Grassland birds	0.1 km	Variety	Have buffer when grassland in >5 acres. Important habitat for species such as Northern Harrier, Barn Owl, and Grasshopper Sparrow.	State-wide
Scrub-Shrub birds	0.1 km	Variety	Have buffer when shrubs are >3 acres. Important habitat for Yellow-breasted Chat.	State-wide

Species	Distance	Conservation status	Comments	Towns where documented
Wading/Shore birds	1 km	Variety	Buffer for key stopover habitat during migration at coastal ponds and mudflats in southern Rhode Island and Block Island	Westerly, Charlestown, South Kingstown, Middletown, Narragansett Bay Islands, New Shoreham

A variety of methods exist to both predict potential impacts of wind energy facilities on bird and bat populations before a project is constructed, and to evaluate impacts once a project is operational. Pre-construction assessments serve to identify threatened or sensitive species and habitats, enable selection of sites that minimize the change of wind turbine impacts on birds and bats, and to estimate losses from collision, barotraumas, habitat loss, displacement, and behavioral changes. Pre-construction assessments can also help identify habitat locations of particular concern. This category includes habitats that will be displaced by a proposed wind facility as well as habitats in the surrounding landscape that may suffer fragmentation as a result of facility development. Potential habitats of concern include maternity roosts, nesting areas, hibernacula, migration stopovers and routes, wintering ranges, male display areas, and coastal migration drop-out zones (USFWS 2011). Pre-construction assessment surveys may draw on a suite of counting methods, including point-count surveys, transect surveys, hawk watch surveys, territory mapping, raptor nest surveys, radio telemetry, and acoustic monitoring (Strickland *et al.* 2001, USFWS 2011). For bats, the most common methods are roost searches, mist-netting, and acoustic monitoring (Strickland *et al.* 2001).

Post-construction surveys serve to assess the extent of collision, barotraumas, habitat loss, displacement, and behavioral changes of birds and bats associated with a new wind energy facility (USFWS 2011). Radar and heat-sensing technologies can be used to track flight paths, providing data on avoidance behavior (Drewitt and Langston 2006; USFWS 2011). Searching for bird and bat carcasses around turbines provides an estimate of collision fatalities. Post-construction assessments can also be used to measure the impact of techniques implemented to mitigate negative effects on birds and bats.

If significant impacts are detected post-construction, a project owner may choose to employ some method of mitigating these impacts. Attempts to mitigate bird and bad mortality at wind energy facilities have met with mixed results. In one well-studied example, constructing taller, smoother towers with large blade sizes and slower blade speed was more successful at reducing bird and bat mortalities than other techniques, such as shutting down turbines at crucial habitat usage times (Smallwood and Karas 2009). For bats, shutting down wind power generation during periods of slow wind speed, when bats are most prone to collision, has proven effective (Baerwald *et al.* 2009), or raising turbine cut-in speed during known times of bat migration (Arnett, et al. 2010).[5] Altering turbine coloring or lighting to lessen the attraction of birds or situating auxiliary structures (power lines, substations) in such a way as to avoid negative impacts to habitat for important to avian species have also been suggested as potential mitigation options. Use of electromagnetic radiation devices has also been used successfully to deter bats from wind turbines; however, exposure to electromagnetic radiation can harm bats by causing hypothermia and decreasing their ability to echolocate (Nicolls and Racey 2007).

The most comprehensive source on pre- and post-construction assessments of bird/bat interactions with wind turbines is the U.S. Fish and Wildlife Service (2011) Voluntary Land-Based Wind Energy Guidelines. These guidelines, intended to help wind energy developers comply with federal laws governing protection of birds and endangered species, are described in more detail in Section 5.1 of this chapter. Based on the USFWS Guidelines, Paton *et al*. (2012) developed a set of voluntary wind energy siting guidelines tailored for Rhode Island.

3.7 Cultural and Historic Impacts

SECTION SUMMARY

- The environment around a wind turbine may contain historic buildings, artifacts, and landscapes; sites of cultural importance to Native American tribes; and sites valued for their scenic or recreational value. Historic sites are located throughout Rhode Island.
- Wind turbines can cause both direct and indirect effects on historic and cultural sites when not sited carefully.
- As historic and cultural sites are often unique and irreplaceable, many are legally protected by the federal National Register of Historic Places, the Rhode Island State Register of Historic Places, municipal historic districts, and/or the Narragansett Indian Tribe Historic Preservation Office.
- Consultation with the Rhode Island Historical Preservation & Heritage Commission is required for land-based wind energy projects funded by federal, state, or local funding or if they require state or federal permits. Projects which are entirely private undertakings are not subject to review unless a federal or state permit or license is required. Consultation and review will determine whether the proposed project will harm a resource which is on or eligible for the National Historic Register.

Wind turbines can impact historical and cultural sites either directly or indirectly. Direct impacts include physical damage to a site, alteration of the land a site is located on, and obstruction of access to a site for cultural appreciation. For instance, a direct impact might occur

[5] Available evidence suggests that nights with low winds (<6 m/sec) are when most bat mortalities take place (Arnett et al. 2008a, 2011). In addition, there appears to be a negative relationship between stormy nights and bat mortality rates (Kerns et al. 2005). Based on these observations and research by Arnett et al. (2011), we recommend that during nights with high potential for bat migration, and hence bat mortality, that the operational wind speed for wind turbines be 11 miles per hr (6 m per sec), rather than 8-9 miles per hour to start power generation. This would result in a <1% reduction in power production, yet could result in up to a 93% reduction in bat mortality (Arnett et al. 2011).

when a turbine located on public lands is fenced off, blocking access to the land for recreational use, or when excavations for a turbine disrupt ancient burial grounds. Indirect impacts are those that do not materially affect a historic or cultural site but infringe on the use of that site by introducing a foreign structure into the viewshed and/or creating noise impacts that interfere with appreciation of the site's cultural or historic value. Indirect effects on the experience of historic or cultural site resulting from seeing or hearing a wind energy project are not well documented (NRC 2007) and may be harder to predict and prevent than direct effects.

Historic sites: The historic environment around a proposed turbine includes archaeological remains; historic structures, buildings, and landscapes; and sometimes the historic character of the wider landscape (English Heritage 2005). In Rhode Island, many such places are designated as historic districts. The effect of a wind turbine on historic uses depends on whether the turbine's appearance clashes with the historic essence of the site (NRC 2007). On Cape Cod, several proposed wind turbine projects have been cancelled or held up due to objections citing their effects on local historic districts (Cassidy 2009). Archeological inventories of a proposed wind turbine site are generally required in most states before construction can begin (NRC 2007).

Sacred sites: Sites of spiritual importance to Native American tribes may be located in places not be known to outsiders and may be vulnerable to impacts of wind turbines and turbine construction in unique ways (NRC 2007). Several proposed wind energy projects around the country have been held up due to proximity or overlap with sites of tribal spiritual significance. For instance, members of the Kumeyaay, Cocopah, and Quechan tribes have formally objected to a proposed wind farm in California because the land selected contains six burial sites, 400 archaeological sites, and several ceremonial sites considered important by the tribes (Raftery 2012). In New England, the Wampanoag Tribe of Gay Head has objected to the proposed offshore Cape Wind project, citing concerns that the turbines would affect burial sites now underwater due to sea level rise and would interfere with the unobstructed views of the sunrise required for prayer ceremonies (Toensing 2011).

Recreational sites: Wind turbines can affect recreational uses in both positive and negative ways. Negative impacts can occur when access to public lands is blocked or when the scenic values critical to the recreational experience of an area are felt to be diminished by turbines. Turbines can also affect the safety of recreational use of an area through risk of ice throw or by altering opportunities for viewing wildlife, such as birds (Vermont Department of Forests, Parks, and Recreation 2004). Positive impacts can occur in cases where wind turbines become tourist sites (NRC 2007) or when construction of wind turbines opens new access roads to the public to explore new scenic places (Vermont Department of Forests, Parks, and Recreation 2004).

Many of the cultural and historic impacts of wind turbines are not unique to turbines, but are common to all large and visible structures, including tall buildings and cell phone and radio towers. However, wind turbines are also unique among structures because of their moving parts. Moreover, because wind turbines require high wind speeds, they are frequently located in visible places (e.g., ridge tops, fields, coastlines) in undisturbed landscapes away from urban or industrial areas, where wind resources are at their best. These are often areas that are also valued for their cultural appeal and well preserved historic sites (English Heritage 2005).

In one sense, visual and acoustic effects of wind turbines on cultural and historic resources can be thought of as a subset of the more general category of visual and acoustic impacts of wind turbines on surrounding areas (see Section 3.4 Acoustic Impacts and Section 3.8 Aesthetic and Visual Impacts). What makes this subset of effects different from that larger category is that historic and cultural resources are unique and irreplaceable. Moreover, the heritage value of a historic site imbues it with a special kind of value. According to an Australian study on the impact of wind turbines on heritage,

> "[H]eritage is a valuable cultural resource that is non-renewable and becoming increasingly scarce. Heritage is important not just because it might be old, but because it can tell us about our history and can inform us on how our values have been shaped over time. While heritage can be beautiful to look at, it can also provide a wealth of information about the community that lived there in the past as well as today. Heritage gives identity to and inspires present and future generations" (Heritage Council of New South Wales 2003).

Not all historic or cultural sites are equally appreciated, and some may require more protection than others. For instance, sites that receive more visitors are arguably more important to protect than less popular or well-known sites (Masser 2006). Evaluating the sensitivity of sites along a spectrum of historical and cultural value is a somewhat subjective exercise. It should be noted that landscapes that are most "historical" are not necessarily those that will be most affected by installation of a wind turbine nearby. According to English Heritage (2005),

> "While all landscapes are the product of human intervention and are therefore historic to some degree, some have been far more dynamic over time or have altered more radically than others. These historically dynamic landscapes, particularly those where the prevailing character is industrial or agriculturally intensive, may be more suited to accommodating large-scale wind energy developments than less dynamic areas." (pg. 8)

The trickiest component of evaluating impacts of wind turbines on cultural and historic resources is the need to understand the value that their setting bestows on the resource being evaluated. Setting involves topography, land use, and views, and is not just aesthetically but historically relevant (Masser 2006). Key to understanding the value of setting is identifying the reasons that explain a particular site's historical or cultural uniqueness, and how this uniqueness frames visitors' experiences of the site. In some cases, the special character of the historic or cultural site may not be affected by a wind turbine, while in others, installation of a wind turbine may cause a site to lose some of its heritage value by detracting from its historic or cultural value (Heritage Council of New South Wales 2003).

- To predict and evaluate the indirect effects of turbine visibility on historic and cultural sites, communities may wish to consider the following (English Heritage 2005):
- Visual dominance: Where a vertical historic feature (such as a hilltop monument or church spire) is the visually dominant feature in the surrounding landscape, adjacent construction of turbines may be inappropriate.
- Intervisibility: Some historic features may be intended to be seen from other historic sites. Construction of wind turbines may interrupt the line of sight required for intervisibility.
- Movement, sound or light effects: Wind turbine movement may cause overshadowing or disruption of the experience of important historic sites.
- Unaltered settings: The areas around some historic sites may be little changed from the period when the site was constructed or abandoned. The value of unaltered settings may be especially vulnerable to modern intrusions such as wind turbines.

Cultural and Historic Impacts in Rhode Island

Rhode Island has a dense concentration of sites of historic and/or cultural value. According to the Rhode Island Historical Preservation and Heritage Commission,

> "From sites yielding evidence of prehistoric encampments, to eighteenth-century farms, to commercial buildings of the early twentieth century, our history can be traced by what remains on the landscape. The preservation of these remnants helps us to retain our sense of history and community. It also aids in the education of our children and our new residents by showing them, through the history embodied in their everyday surroundings, the depth and breadth of our common heritage" (RIHP&HC 2012).

Rhode Island historic and cultural resources include old houses, neighborhoods, factories and mills, commercial buildings, downtown streetscapes, and historic landscapes such as campuses, cemeteries, farms, gardens, golf courses, parks, parkways, and public open spaces. Many jurisdictions have a process for cataloging and protecting these heritage sites in Rhode Island. These include the National Register of Historic Places, the Rhode Island Historical Preservation and Heritage Commission, municipalities' local historic districts, the Narragansett Indian Tribal Historic Preservation Office, and local preservation societies. All of these entities may be helpful sources of information when considering the potential historic and cultural impacts of a wind turbine.

National Register of Historic Places: The National Historic Preservation Act (16 U.S.C. 470 et seq.) of 1966 established a National Register of Historic Places to catalog buildings, sites, districts, and objects worthy of preservation. Rhode Island has over 19,000 sites listed in the

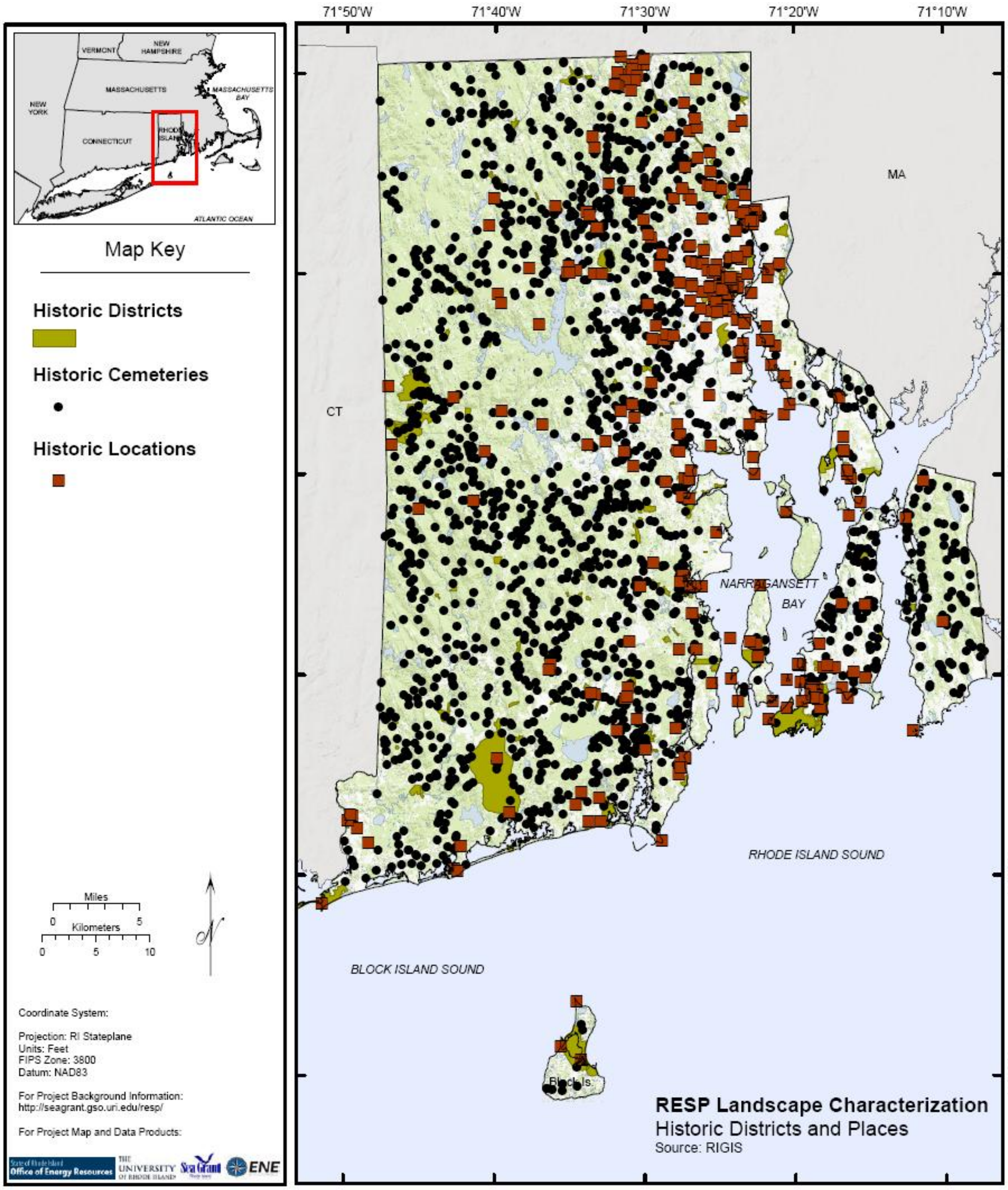
National Register of Historic Places. These include colonial houses, farms, Victorian neighborhoods, factory villages, diners, monuments, military bases, seacoast villages, suburban neighborhoods, and more (RIHP&HC 2012). Sites on the National Register of Historic Places are nominated because they present one or more of the following characteristics: (1) an association with events or activities that were important in the past; (2) an association with a person who was important in the history of the nation, state, or local community; (3) historically significant design characteristics, methods of construction, or architectural uniqueness; and/or (4) provision of new information about our past. The National Historic Preservation Act set up a process of review of all federally funded projects which might have an impact on registered properties (see Section 5.2 of this chapter).

Rhode Island Historical Preservation and Heritage Commission: The Rhode Island Historical Preservation & Heritage Commission (RIHP&HC) operates a statewide historical preservation program that identifies and protects historic buildings, districts, structures, and archaeological sites. The Rhode Island Historic Preservation Act (RIGL 42-45 et seq.) is the state authority under which the RIHP&HC administers its programs including the review of state undertakings. The RIHP&HC oversees Rhode Island activities related to the National Register of Historic Places. In addition, the RIHP&HC manages a State Register of Historic Places, which includes all of the sites listed in the National Register and more. The RIHP&HC reviews all federal, federally-funded, or federally-licensed projects to determine whether they will harm a resource which is on or eligible for the National Register. The RIHP&HC also reviews state and locally funded projects for their impact. Projects which are entirely private undertakings are not subject to review unless a federal or state permit or license is required.

Historic Districts: Local historic districts are special zoning areas created through municipal ordinances that help protect historic buildings and preserve the historic character of some parts of a community. Bristol, Cranston, Cumberland, East Greenwich, East Providence, Glocester, Hopkinton, New Shoreham, Newport, North Kingstown, North Providence, North Smithfield, Pawtucket, Providence, South Kingstown, and Warwick have historic zones. Historic zoning was enabled by the General Assembly's 1959 historic district zoning legislation, which authorizes cities and towns to pass special ordinances to protect their historic buildings and areas and to create municipal commissions to review proposed changes for those buildings. In addition, all Rhode Island municipalities have comprehensive plans that include a section on preservation of historic resources. Ch. 1 Figure 29 depicts historical districts located in Rhode Island.

Narragansett Indian Tribal Historic Preservation Office (NITHPO): NITHPO is the office of the Narragansett Indian Tribal administration authorized to represent the tribe on matters relating to historic preservation, graves protection, religious freedom, and other relevant cultural matters. NITHPO’s priorities include protecting tribal ancestors' memories, histories, and living places.

Preservation Societies: There are over 100 historical and preservation organizations in Rhode Island. The largest among these are the Rhode Island Historical Society, the Newport Historical Society, the Providence Preservation Society, the Preservation Society of Newport County, and Preserve Rhode Island. Most other historical and preservation organizations are small, volunteer-run associations, focused on a single community or property.



Ch. 1 Figure 29. Historic Districts and Historic Cemeteries in Rhode Island.

*Note: this map does not contain National Register-eligible properties, nor is it updated regularly. The Rhode Island Historical Preservation and Heritage Commission should be consulted on the presence of historic resources.

3.8 Aesthetic and Visual Impacts

SECTION SUMMARY

- Wind turbines are large and can be visible from a distance. Some people may consider wind turbines a negative impact on the landscape, while others may find that they enhance a landscape.
- The visual impact of wind turbine will likely be greatest in areas valued for their scenic qualities.
- Visual impacts can be assessed through community review of visual simulations of what a proposed turbine would look like in a given setting.

Installation of wind turbines adds a new element to local vistas. While some people may be indifferent or even favorably disposed to the addition of this element, others may find it distasteful. Strong objections to visual impacts are one of the most difficult types of friction to resolve (Coles and Taylor 1993; Lindley 1994; New York State Energy Research and Development Authority 2009).

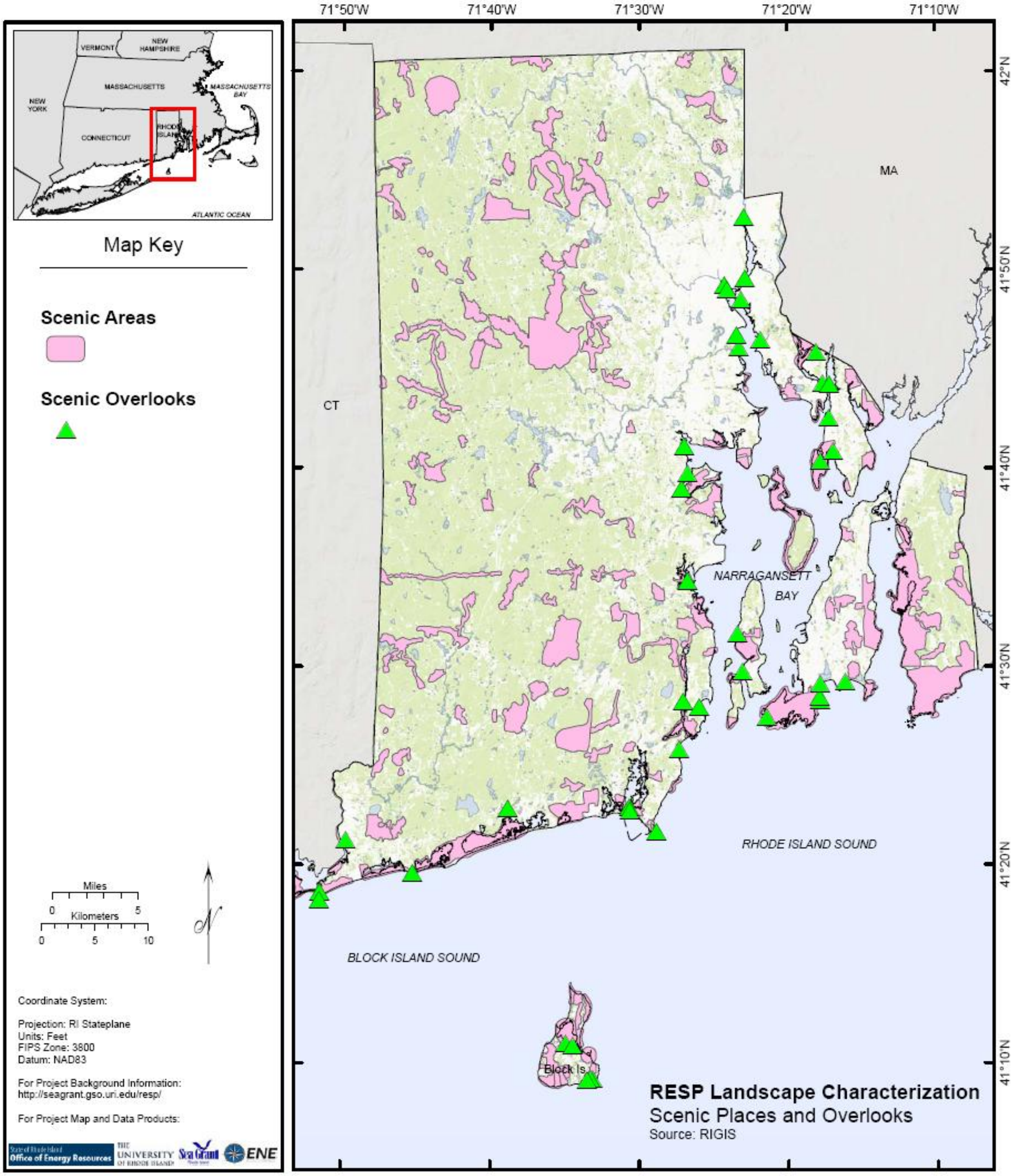
Observers have noted the role of wind turbine visibility in producing a "bipolar" response to wind energy. This type of situation unfolds where some local residents are strongly in favor and others strongly opposed to the installation of turbines (Cownover *et al.* 2010). Even though surveys suggest that the public is willing to accept the location of wind energy facilities much closer to their homes than they would accept any other kind of energy facility, experiences around the world also show that wind energy debates frequently feature a high percentage of people who support wind energy in theory but object to siting of turbines near their homes (Cownover *et al.* 2010). Although visual impacts of wind turbines are only one reason that neighbors may object to siting turbines nearby, they are often a deep-seated one.

However, visual impacts do not take place with every wind energy project, and even when they do, they are not always considered detrimental. Moreover, visibility of a turbine does not automatically equate to a visual impact on the community (Vissering *et al.* 2011). In a best case scenario, visibility of wind turbines can have a neutral or positive effect on the enjoyment of landscapes. In a worst case scenario, the appearance of visible wind turbines on the horizon or in the neighborhood could pose a negative impact or interfere with the enjoyment of the viewscape. The precise point at which each new project falls along this spectrum tends to be highly dependent on the siting of the wind turbine, characteristics of the turbine, and overall psychological relationship to the landscape held by residents.

As an illustration of these points, visual impacts associated with wind turbines may be most severe in rural, coastal, or other scenic areas prized by residents for their unadulterated views of nature (Lothian 2006; NYSERDA 2009). The relationship of residents to surrounding landscapes in such areas may be affected subjectively if residents have a habit of enjoying panoramic views of a landscape and appreciating the absence of manmade structures in the view.

It may also be affected objectively by increased visibility in an area uncluttered by other artifacts. However, it is not axiomatic that the addition of wind turbines to such an area will be construed by local stakeholders as a negative change. For instance, a study in Scotland found that most tourists considered wind energy a neutral or positive addition to scenic landscapes (MORI Scotland 2002). The degree to which visual impacts caused by a new wind turbine are considered problematic is sometimes influenced by cumulative impacts produced by the new turbine in conjunction with other, existing structures within a particular landscape. This need stems from the fact that while one landscape element may not alter the character of a landscape on its own, several structures erected over time may produce a cumulative impact on the appearance of the landscape (Scottish Natural Heritage 2005). Multiple structures may include several wind turbines or a combination of wind turbines and other structures (Scottish Natural Heritage 2005). Cumulative impacts may occur in cases of *combined visibility*, when two or more turbines or other structures are visible from the same vantage point, or in cases of *sequential effects*, when the observer perceives multiple turbines in succession while moving through a landscape (Scottish Natural Heritage 2005). In sum, presence and character of manmade and natural landscape features that predate or coincide with the installation of a new turbine may play a role in how the public perceives the aesthetic impact of the turbine.

Rhode Island possesses many areas considered scenic by residents and visitors alike. Ch. 1 Figure 30 shows a map of identified scenic areas and overlooks in Rhode Island. As Ch. 1 Figure 30 shows, many of the areas considered scenic in Rhode Island are located along the state's coastline. Because coastal areas also offer the most abundant wind resources in the state (Merrill and Knorr 2012), objection to the visual impacts of wind turbines on coastal views can be expected to arise when siting wind turbines in the state.



Ch. 1 Figure 30. Scenic Places and Overlooks in Rhode Island.

Anticipating visual impacts

The probability that installation of a new wind turbine will have visual impacts considered negative by community members can be predicted and mitigated by examining a number of different variables. Ch. 1 Table 11 presents a list of objective factors affecting the visibility of wind turbines, while Ch. 1 Table 12 presents a list of subjective factors that mediate the degree to which visibility is considered negative. Both lists draw on empirical research from around the world on the visual impacts of wind turbines and other structures, and on modeling exercises performed to simulate visual impacts.

A key point emerging from previous research is the relational nature of visual impacts. That is, physical relational factors (e.g., distance between an observer and a wind turbine, height of a turbine compared to surrounding objects) come into play when community members evaluate the visual acceptability of wind turbines. For instance, studies show that observers perceive no difference in height between a 200-ft (61m) turbine and a 400-ft (122m) turbine when the turbines are at a distance, unless the two are side by side (Vissering *et al.* 2011). Studies also show that observers find a turbine more visually noticeable if it appears larger within their frame of reference than a nearby mountain or other landmark (Vissering *et al.* 2011). In addition, movement is a key part of an observer's frame of reference; if a wind turbine is continually visible as observers travel a road or other thoroughfare, the length of time during which the wind turbine is visible may also be a factor in assessing visual impact (Vissering *et al.* 2011).

Ch. 1 Table 11. Physical factors mediating wind turbine visibility.

Factor	Relationship	References
Distance	Turbines between ½ and 4 miles (0.8-6.4km) from an observer are most noticeable. Within distances less than ½ mile (0.8km), turbines appear as part of one's immediate surroundings and not seen in their entirety. In distances greater than 4 miles (6.4km), atmospheric haze begins to mask turbines from view (this distance can be greater in dry, flat landscapes). Aside from these parameters, there may not be a clear one-to-one relationship between distance from a turbine and perceptions of visual impact.	Vissering *et al.* 2011; Lothian 2006.
Topography	In flat landscapes, the visibility range is larger. Varied topography can obscure turbines from view.	NYSERDA 2009; Vissering *et al.* 2011
Atmosphere	Atmospheric scattering caused by vapor and smog can reduce the perceived contrast between a turbine and its surroundings, making it less visible.	Bishop 2002.
Turbine size	The taller the turbine, the larger the viewshed.	Vissering *et al.* 2011
View duration	For turbines visible from roads, rivers, and other paths of travel, the length of time that turbines are visible to travelers may affect how intrusive the turbines are perceived to be.	Vissering *et al.* 2011

Number of turbines	Greater numbers of turbines within a view shed tend to be more visible than one or a few, and are often considered more visually intrusive.	Vissering *et al.* 2011
Angle of view	Turbines positioned directly in front of a vantage point are generally more noticeable than those to the side.	Vissering *et al.* 2011
Lighting	Hazard lighting makes turbines more visible at night.	NYSERDA 2009; Vissering *et al.* 2011
Wind speed consistency / Turbine activity level	Moving turbine blades are "transparent"; when blades are stationary, they are not only more visible but cause viewers to doubt their functionality.	Cownover *et al.* 2010
Accompanying roads and structures	The visibility of wind turbines may be greatly enhanced if accompanied by new structures and roads, particularly when roads are placed on slopes.	NWCC 2002.
Season	Turbines tend to be more visible during winter, when surrounding trees are bare.	NYSERDA 2009

Ch. 1 Table 12. Objective and subjective factors mediating visual impacts caused by turbines.

Factor	Relationship	References
Character and scenic quality of a landscape	Impacts tend to be greater when wind turbines are installed in rural and "intact" landscapes and in landscapes with unique or rare features. In landscapes of "lower" scenic quality, wind turbines have been found to enhance residents' appreciation of the landscape.	Bishop 2002; Lothian 2006; Vissering *et al.* 2011
Topography	Landscapes with more varied topography are more likely to be considered scenic.	Vissering *et al.* 2011
Cognitive and affective responses towards wind turbines	A person's general feelings towards wind turbines (positive/negative) play a role in determining a person's visual assessment (attractive/ugly) of wind turbines. These feelings can be mediated by beliefs in renewable energy, economic benefits, or concern for birds, among other things.	Bishop 2002; Cownover *et al.* 2010
Economic benefits	When turbine neighbors receive a tangible economic benefit from the turbine, they tend to find it more visually appealing.	Thayer and Hansen 1988.
Turbine array	Where multiple turbines are present, uniform arrays of similar turbines tend to cause a lesser visual impact than haphazard arrays of dissimilar turbines.	Cownover *et al.* 2010
Turbine spacing	Where multiple turbines are present, a more bunched spacing tends to be less appealing than a more spread out array.	NWCC 2002.
Site treatment	Visual impacts can be exacerbated by accompanying infrastructure (wires, roads, buildings), and lack of site grading.	Cownover *et al.* 2010

Compatibility with surrounding landscape	Visual compatibility should be broken down into its most basic elements (line, form, color) to understand how each will impacted individually, then as a whole. Visual displeasure tends to be greater when a turbine interrupts or breaks the continuous patterns of the line, form, or color in the landscape, and when arrays of turbines do not echo the features of a landscape. For instance, the public tends to prefer orderly arrays in ordered landscapes, and randomly clustered arrays in more complex landscapes. This is one of the underlying reasons turbines are considered more visually acceptable in an urban landscape.	Phadke *et al*. 2009.

Potential visual impacts can be assessed prior to a project through visual impact assessment and public input. Visual impact assessments are systematic analyses of potential impacts to scenery resulting from a proposed development. A complete assessment incorporates both objective and subjective considerations and performs formal evaluations of mitigation measures (Macaulay 2010).

The tools used in visual assessment are of major importance to the resulting product and impact determination. The most important element is that the procedure follows a scientific and defensible process. Zone of Visual Influence (ZVI) maps or "Viewshed Maps" are computer generated and allow the specialist conducting the visual analysis to input the height and location of each project element. The computer will then scan every cell of a digital elevation model within a given distance of the project and determine whether the project will be visible that geographic location under bare earth conditions. Vegetation can also be added to the analysis for more accurate results. This method is useful for determining general areas where project visibility may require additional visual analysis. For those areas with a view of the project, the following list outlines the minimum requirements in many states across the U.S. for visual assessments:

- Photographs must be taken a clear day from several publically accessible locations (especially historic and scenic resources).
- The proposed project must be unobstructed or as minimally obstructed as possible from each location.
- Visual simulations must be produced at several locations. In this process, a trained technician produces a virtual camera in a 3D computer application which is aligned to the actual field camera conditions. The proposed project is placed at an accurate scale into an existing photograph and several field elements are introduced to the model to verify the accuracy of the alignment. Sun or daylight systems are introduced to the model to ensure the lighting and atmospheric conditions match the base photograph.

Such simulations must depict not only the proposed turbine, but also any new roads, buildings, and wires planned in association with the turbine (Vissering *et al.* 2011). Builders of simulation models may choose to simulate the proposed turbine(s) in different atmospheric conditions, seasons, and times of day, and with blades both stationary and moving, to offer community members a chance to evaluate views of the proposed turbine under a full range of conditions. For more information on creating visual simulations see Perkins (2012).

After simulated images have been developed, they are then reviewed by planners and the public. This analysis typically considers the following questions (NYSERDA 2009):

- **Objective:**
    - How visible is the turbine from each location?
    - When is the turbine visible from each location, in terms of both season and time of day?
    - To whom is the turbine visible, and what activity are they performing when they see it: recreation, working, shopping, driving, or something else?
- **Subjective:**
    - To what extent does visibility of the turbine alter the character or quality of the viewshed?
    - What is the relationship between visual impacts and community values in the region?

Responses to these questions are useful for informing answers to the larger question of whether a wind energy development, as proposed, imposes unreasonable visual impacts on members of the community. If a visual simulation and community review process determines that a proposed project imposes unreasonable visual impacts, several mitigation measures are available including:

- Using an appropriately sized turbine for the site (NYSDEC 2000; Vissering *et al.* 2011);
- Minimizing the number of turbines or area covered by turbines (NYSDEC 2000; Vissering *et al.* 2011);
- Adapting lighting plans to make nighttime visual impact as unintrusive as possible (NYSDEC 2000; Vissering *et al.* 2011);
- In multi-turbine projects, arranging turbines in patterns that fit with the landscape (Vissering *et al.* 2011);
- Burying wires related to the installation (Vissering *et al.* 2011);
- Avoiding logos and garish colors on turbines; prefer grey or off-white (NYSERDA 2009; Vissering *et al.* 2011);
- Using “screens” made of dense vegetation, soil, bricks, rocks, or any other opaque object to obscure wind turbines from view (NYSDEC 2000);
- Avoid placing roads associated with wind turbines on slopes, where they are more visible from a distance (NWCC 2002);
- Decommissioning a project as soon as its useful life is over (NYSDEC 2000).

3.9 Property Values Impacts

SECTION SUMMARY

- The effect of wind turbines on property values can be a prime concern among community members during the wind turbine siting process.
- The potential for wind energy facilities to cause impacts on nearby property values has been assessed through analog studies, stated preference surveys, studies of real estate values or sales data, and surveys of expert practitioners.
- Analog studies attempt to anticipate the property-values effects of wind energy projects by looking at impacts associated with other land uses, such as utility transmission lines, highways, and power plants. These other uses have been found to result in declines in property value of anywhere from 0% to 16%, which may represent an upper bound on the effects of wind turbines, since turbines are often considered less undesirable than these other uses.
- Stated preference surveys ask residents living near existing or proposed wind turbines to discuss perceived or anticipated effects of wind turbines on property values. This chapter reviews three stated preference surveys; all indicate some evidence for a perceived or anticipated decline in property values due to existing or proposed wind turbines.
- Studies of real estate values or sales data rely on statistical methods to compare the values of homes at varying distances from a wind energy project, values inside/outside the viewshed of a project, or values before/after a project was installed. This chapter reviews 15 such studies. Of the studies reviewed, nine failed to find evidence of a negative impact of wind energy projects on property values, three found some evidence for negative impacts, and two found both negative and positive impacts. In addition, two studies found evidence showing that the anticipation of a wind turbine has a more negative effect on home sales prices than the wind turbine once constructed.
- Expert opinion surveys rely on the judgment of real estate agents, appraisers, town officials, or surveyors to estimate possible impacts of wind energy projects on property values. This chapter reviews three expert opinion surveys. Two found some evidence that experts associate a negative impact on property values with the presence of a wind energy project; the third found evidence that experts do not believe such a link exists.
- Anecdotal evidence offered by homeowners and others whose personal experience has given them insight into the relationship between property values and wind turbines, albeit on a very small and individualized scale, is frequently cited in debates about the effects of wind energy projects on property values. Because of their small sample size, these accounts cannot distinguish between the influence of wind turbines and other factors affecting property values. Nonetheless, these accounts may provide useful information for improving case-specific understandings of how property values change near wind turbines. Like large-scale market analyses, most anecdotal accounts refer to wind farms, not single turbines.

- Most studies and anecdotal accounts to date focus on multi-turbine wind farms in rural areas. Their findings may not be 100% transferable to situations like Rhode Island, where population density is high and single-turbine projects are the norm.
- Compensation of property owners affected by wind energy projects by project developers is an emerging approach to dealing with the potential for negative effects on property values. Only a few instances are known, and few details are available.

Potential impacts of wind energy development on nearby property values are a frequent cause for concern among community members during the turbine planning and permitting process. Apprehension over the impact of wind energy on property values can stem from concerns about noise, shadow flicker, aesthetic impacts, and other possible effects of wind energy on surrounding homes. Although the property values issue is in some ways an extension of these other issues, it is also an issue in its own right. In some cases, a perception that one's investment in a home may decline in value as a result of a nearby wind energy project may cause more concern than the possibility of personally experiencing shadow flicker, aesthetic impacts, or noise.

Although concern over the impacts of wind energy development on property values can run high in some communities, no consistent relationship between these two variables has been yet been established by scholarly analyses. While it seems plausible that property values may in some cases diminish as a result of the noise, shadow flicker, or visual effects associated with wind turbines (just as they may diminish due to traffic noise, airport noise and lighting, and other sources of disamenity[6]) studies on the topic have not yet come to consensus over whether, where, and when such effects are likely to occur.

Hoen *et al.* (2009, 2011) have classified potential negative effects of wind turbines on property values into three types. "Area stigma" describes a phenomenon wherein properties are devalued by perceived "industrialization" of the area. Area stigma may be particularly relevant in areas valued for tourism, second homes, or bucolic scenery. "Scenic vista stigma" may occur as a result of a loss in quality of scenic vistas visible from homes. Lastly, "nuisance stigma" may occur when properties are devalued due to the existence of shadow flicker, acoustic impacts, or other aspects which intrude upon residents' day to day life. All three of these impacts are context-based and subjective, and can be expected to vary from place to place and person to person. Scenic vista stigma, in particular, tends to be affected by subjective evaluations regarding the aesthetic effects of wind turbines and the aesthetic value placed on views prior to installation of turbines: Carter (2011) found that while some homeowners may see wind turbines as an unappealing intrusion on their views, others find them aesthetically pleasing and value them as a symbol of clean, green energy.

[6] Just as an "amenity is a "feature that provides comfort, convenience, or pleasure" (from www.dictionary.com), a disamenity is "a disadvantage or drawback, especially of a location" (from www.wiktionary.com).

The subjective nature of the effects of wind turbines on property values does not necessarily offer any reassurance to homeowners residing near a proposed wind energy site. In fact, the subjective and individualized experience of visual and acoustic effects of turbines may only compound the apprehension felt by homeowners, since future buyers of a property may be affected by turbines even if current owners are not. The unknown nature of subjective impacts on future prospective buyers may make it hard for current owners to gauge the predicted effect of turbines on the potential selling price of their property.

The following questions may serve as a guide for evaluating possible effects of wind energy projects on property values. Careful attention to these questions can inform siting and mitigation practices that protect home property values from any potential effects associated with wind turbines.

- Do wind turbines affect the value of surrounding residential properties? If so, do impacts tend to be negative or positive?
- How consistently do such impacts occur? Do impacts vary with geography, technology, cultural attitudes, and other factors?
- What aspects of wind energy are most relevant to home property values – noise, shadow flicker, visual/aesthetic effects, or others?
- How large is the radius of effects around a turbine? What is the maximum distance at which wind turbines affect property values? How quickly does a potential impact attenuate with distance from a wind turbine project?
- Under what conditions (e.g., existing land use patterns, scenic character of an area, preexisting property values) are wind turbines likely to cause negative impacts to property values?
- What characteristics of a wind energy facility (e.g., number of turbines, height, design and technology) influence the impact that it has on property values?
- How large is the degree of change in property values, if and when it occurs, resulting from installation of a wind facility nearby?

Answering these questions can be challenging. Academic methodologies relevant to this task include analog studies (exploration of property-values impacts associated with utility transmission lines, highways, and other types of development that may be associated with disamenity); studies of stated preferences among residents living near existing or proposed wind turbines; studies of real estate values or sales data; and surveys of experts (e.g., real estate agents and appraisers). An additional source of information are the anecdotal accounts offered by homeowners and others whose personal experience has given them insight into the relationship between property values and wind turbines, albeit on a very small and individualized scale. Each of these methods presents a partial picture of the complicated and nuanced relationship between wind turbines and property values, and studies of this relationship have presented a mixed message. The remainder of this chapter summarizes current studies and other informational sources that have attempted to characterize this relationship. The chapter concludes with some options for mitigation and avenues for future research.

Analog studies

Since study of the property values effects of wind energy facilities is a relatively new endeavor, some analysts suggest drawing on a more established body of literature on the property values effects of different yet comparable types of development. Power plants, highways, high-voltage transmission lines, landfills, and airports are just a few types of development with the potential to affect property values in negative ways. The mechanisms through which these types of development affect property values (e.g., noise, odor, aesthetics, traffic, etc.) vary; what they have in common is that all are generally considered undesirable. Wind turbines, in contrast, are often viewed positively, and thus precise findings on these other disamenities may not be directly transferable to wind turbines (Hoen, personal communication, February 14, 2012). Because of this distinction, Hoen (2012) argues that data on the impacts of these other disamenities serve only to set upper bounds on the negative impacts that could be anticipated to occur as a result of wind turbine development.

Ch. 1 Table 13 shows the extent of influence of various types of disamenity on nearby property values. These disamenities have been found to result in declines in property value of anywhere from 0% to 16%. The highest rates of decline appear to be associated with crematoriums, Superfund sites, and waste transfer stations. Since the clean energy provided by wind energy often enjoys high levels of support among the public, it appears unlikely that wind turbines would cause declines greater than those caused by other disamenities (e.g., 16%), according to Hoen (2012).

Ch. 1 Table 13. Findings on the impacts of various disamenities on nearby property values. Reprinted from Hoen (2012).

Crematory	Agee and Crocker (2008)	Rawlings, WY	-2% to -16%*	within a mile	
Superfund	Gayer et al. (2000)	Grand Rapids, MI	-4% to -6%*	within a mile	
Superfund	Kiel & Zabel (2001)	Woburn, MA	-15%	within a mile	
Groundwater Contamination Pre Remediation	Case et al. (2006)	Scottsdale & Tempe, AZ	-7%	in currently contaminated area	
Groundwater Contamination Post Remediation	Case et al. (2006)	Scottsdale & Tempe, AZ	no difference	in previously contaminated area	
Waste Transfer Station	Eshet et al. (2007)	Israel	-12%	within a mile	
Industrial - Superfund	Carroll et al. (1996)	Henderson, NV	-7%	within a mile	2.5 miles
Lead Smelter	Dale et al. (1999)	Dallas, TX	-0.8% to -4%	within a mile	2 miles
Power Plant	Davis (2008)	assorted	-3% to -5%	within 2 miles	
Landfill - High Volume	Ready (2005)	assorted	-13%	adjacent to landfill	2 miles
Landfill - Low Volume	Ready (2005)	assorted	0% to -3%	adjacent to landfill	2 miles
Landfill	Reichert et al. (1992)	Cleveland, OH	-5% to -7%	within a few blocks	
Landfill	Thayer et al. (1992)	?	-2% to -5%	within a mile	4 miles
Transmission Line	Hamilton & Schwann (1995)	Vancouver, Canada	-6%	adjacent to tower	330 feet
Transmission Line	Des Rosiers (2002)	Montreal, Canada	-10%	adjacent to tower	150 feet
Road Noise	Batemen et al. (2001)	Glasgow, Scotland	-0.2% to -2%	increase of 5 dBA**	
Road Noise - 29 Study Review	Batemen et al. (2001)	assorted	0% to -11% (2% median)	increase of 5 dBA**	

** based on 2008 median house price (source: city-data.com)*

*** 10 dBA roughly represents the difference in noise between a busy road and a quiet street*

Grover (2002) proposed that property values effects of high-voltage transmission lines (HVTLs) may represent an appropriate upper bound to the effects that can be anticipated to occur with wind turbines. A literature review revealed that HVTLs have been found to result in a maximum reduction in nearby property values of 10%, and that values appear to rebound over time (Grover 2002). Since HVTLs are almost universally considered unattractive (unlike wind turbines, which can at times be considered aesthetically pleasing), Grover (2002) suggests that any impacts resulting from wind turbines can therefore be expected to be less than this 10% reduction.

Stated preference and attitude surveys

A rough sense of the potential effects of wind turbines on nearby property values may be gained by consulting residents on their attitudes towards existing or proposed turbines. Stated preference surveys rely on residents themselves to make estimates of how they feel their properties have been, or would be, impacted by a wind energy facility. A subset of this type of survey is the willingness-to-pay survey, which asks residents to quantify in monetary terms how much they would be willing to pay to stop a proposed wind energy project or to have an existing wind energy project removed.

Munksgaard and Larsen (1995) interviewed 342 people living in the vicinity of 102 different wind energy facilities in Denmark. When asked about visual effects, 17% of respondents expressed the opinion that wind turbines disfigured the surrounding landscape, while 71% felt that turbines had no visual impacts. When asked to put a monetary figure on their aversion to the turbines, respondents were willing to pay an average of $26 per household per year (0.006 cents/kWh) to have the turbines removed. Willingness to pay to remove the turbines was greater for single turbines than for wind farms (0.019 cents/kWh and 0.003 cents/kWh, respectively).

Bond (2008) interviewed residents in Western Australia and found that while most think of wind farms in positive terms, many respondents reported that they would not want to live 'near' a wind farm, usually stated as between 1-5km (0.62-3.1 miles). Thirty-eight percent of respondents said that the maximum amount they would be willing to pay for their homes, if buying them now, would be 1-9% less than they paid when the bought their homes, prior to installation of the wind energy facility.

Several attitudinal studies have documented that community members often expect wind turbines to negatively affect property values. In a study performed by the Beacon Institute at Suffolk University, Haughton *et al.* (2004) surveyed 501 home owners on Cape Cod and Martha's Vineyard regarding the proposed Cape Wind offshore wind farm in Nantucket Sound. Sixty-eight percent of participating homeowners anticipated that, if constructed, the wind farm would reduce their property values by an average of 4%. Households with waterfront property anticipated an even higher loss in value, on the order of 10.9%. Responses to the survey indicated that that 22% of respondents were willing to pay to ensure that the windmills would not be built, while 9% were willing to pay to encourage a wind energy project in Nantucket Sound. Those opposed to the project were willing to pay an average of $286 per household to prevent the project, while those in favor of the project were willing to pay an average of $112 per household to support the project.

Attitudinal studies have also documented cases where this anticipated decline in value has failed to materialize once turbines are constructed. A study commissioned by the Scottish Executive (Braunholtz 2003) asked 1,547 residents living within 20 km (12.4 miles) of ten large wind farms to state whether they felt that turbines affected house prices in the area. While 7% of the 1,547 respondents replied that they had anticipated that a drop in house prices would occur with construction of wind turbines, only 2% affirmed that declines had indeed occurred in the post-construction period.

Stated preference studies can be useful for gauging general opinions towards wind farms among homeowners, but leave many gaps in understanding the relationship between wind energy projects and property values. Anticipated or estimated changes in property values expressed by homeowners can be highly subjective, and willingness-to-pay studies can overestimate residents' aversions towards projects, since residents are not required to actually make payments. The next section reviews studies conducted using real estate market data. Market analyses are usually considered to be the most thorough and objective approach to examining the effects of wind energy projects on property values.

Market data

Use of market data makes it possible to perform statistical analysis of the relationship between wind energy projects and home property values, which is necessary to infer how significant and/or widespread any potential negative impacts may be. Market data studies can explore the impact of several independent variables (e.g., distance from a turbine, temporal stage of a wind energy project, or the rural/urban character of an area) on several dependent variables (e.g., home sales price, sales volume, or time on the market). Many early market analyses of the relationship between wind energy facilities and property values relied on simple statistics to look for patterns, such as differences in home sales prices in an area before and after the development of a wind energy facility or correlations between home sales prices and distance from a wind energy facility. More recent studies have turned to hedonic pricing models that untangle the effects of proximity to wind turbines from the myriad other factors influencing home sales prices. The findings of market studies neither support nor refute observations by individual property owners or experts, because the nature and goals of the two types of data are fundamentally different. Statistical techniques applied to market data can distinguish broad-scale trends from isolated cases, but their findings cannot be used to assess or predict the impacts of wind turbines on individual properties.

One of the earliest statistical analyses of transaction-based data in the vicinity of wind turbines was conducted by Sterzinger *et al*. (2003) of the Renewable Energy Policy Project (REPP). This group examined over 24,300 property transactions occurring near ten U.S. wind energy projects constructed between 1998 and 2001, all greater than 10MW. Their objective was to determine whether this data set could support the claim that wind energy projects harm nearby property values. The authors performed three comparisons. The first compared the rate of change in sales prices (starting three years prior to wind project construction and ending three years after construction) within the viewshed of a project (defined as the area within a 5-mile, or 8-km, radius of a project) and outside the viewshed. This comparison showed that in eight of the ten projects analyzed, sales prices increased faster within the viewshed than outside the viewshed. The second analysis compared home sales prices within the viewshed before and after wind turbine construction, and found that in nine out of ten cases, sales prices increased faster after wind project construction than before construction. The third compared post-construction sales prices within the viewshed to those outside of the viewshed, and found that for nine of the ten projects analyzed, sales prices increased faster inside the viewshed than outside the viewshed.

The results of this report were admittedly incomplete, since the study did not take into account factors other than wind turbines that could affect property values, such as more general trends in the housing market (Sterzinger *et al*. 2003). In addition, the study does not report whether results are statistically significant. However, as the first large-scale analysis of the effects of wind turbines on property values, this study played an important role in ruling out the possibility that wind turbines have a consistent deleterious effect on home property values.

Subsequent studies have targeted the same questions in different ways. A study prepared by Poletti (2007) for Invenergy Wind LLC examined properties in the vicinity of three wind farms in Wisconsin and Illinois: the White Oak wind farm (100 turbines), the Rosiere wind farm (17 turbines), and the Lincoln wind farm (14 turbines). The author performed T-tests to compare properties within a turbine zone (defined by a combination of distance, intervening land uses, and visibility of the facility) with those in a control zone, but found no significant differences between the two zones in terms of sales price per square foot for residential properties or per acre for agricultural properties.

A sales data analysis performed by Appraisal Group One (Kielisch 2009) for the Calumet County Citizens for Responsible Energy considered two wind farms in Wisconsin: the WE Enegies Blue Sky Green Fields wind farm (88 turbines) and the Invenergy – Forward wind farm (86 turbines). The author compared the sales prices of vacant residential lots inside and outside the perimeter of the two wind farms. Their findings suggest that (1) more sales took place outside the wind farm perimeters than inside, and (2) sales prices within the perimeters of each wind farm were lower than sales prices outside, by 12-47% (average of 30%) and 19%-74% (average of 40%), for each of the wind farms respectively. This is one of few statistical studies of property values impacts of wind turbines to document a negative impact. This study did not evaluate these findings for statistical significance or adjust for other factors affecting land prices.

An analysis performed by Canning and Simmons (2010) for the Canadian Wind Energy Association utilized multiple regression analysis to examine the effects of a 640-turbine (96 MW) wind farm on sales prices in the municipality of Chatham-Kent, southwestern Ontario. Drawing on 83 home sales that occurred in the area between 2007 and 2009, the authors compared sales prices for properties with and without a view of the turbines, and found no statistically significant relationship between these two variables. They also examined 14 repeat sales[7] (13 inside the viewshed and one outside the viewshed), in which the first sale took place prior to wind turbine construction and the second sale took place after construction. Eight of the homes within the viewshed sold for more during the post-construction period than before construction; five of the homes within the viewshed sold for less during the post-construction period than before construction; and the one home outside the viewshed sold for less during the post-construction period than before construction. However, the authors caution that several of the homes in the repeat sales analysis were subject to improvements in the period between sales, while others deteriorated in quality, making it impossible to perform an even comparison.

[7] Repeat sales analyses can be performed when a property has been sold at least twice within the study period: once prior to the development of a wind energy facility, and once after development. The value of this type of analysis is that it controls for all other variables that influence home sales prices.

Magnusson and Gittell (2012), in a study sponsored by Antrim Wind Energy, investigated possible impacts of a 12-turbine (24MW) wind energy project in the Town of Lempster, New Hampshire. This study considered 2,593 arms-length[8] sales of single-family homes, comparing prices before and after approval of the wind power facility. The authors also tested for visual effects by comparing sales prices of homes with no view, partial views, and full views of the turbines. In addition, they tested for area stigma by looking for correlation between sales prices and distance from turbines. Like most studies before them, they found no consistent, statistically significant evidence that property values in the Lempster region are affected by proximity to, or views of, the wind energy project.

Many recent large-scale analyses employed complex hedonic pricing models to analyze the effect of wind turbines on home property values. Hedonic pricing models separate the value of a generic property into its component qualities and characteristics to determine the relative importance for each component. Typical components may include location near the water or the countryside, proximity to schools or transportation, number of bedrooms and bathrooms, acreage, and many other variables which tend to influence the amount that potential buyers are willing to pay for a home. Hedonic studies can be used to assess the impacts of wind turbines on property values by adding one or two variables of interest -- proximity to wind turbines or views of turbines -- as component qualities in this list, and measuring the strength of this variable in determining selling prices.

Sims and Dent (2007a,b) of Oxford Brookes University used a hedonic sales model and comparative sales analysis to examine transaction data for 919 home sales within 0.5-5 miles (0.8-8 km) of three wind farms (consisting of 11, 16, and 10 turbines, respectively) in Cornwall, UK occurring between 2000 and 2004. The study found that some areas around wind turbines exhibited lower sales prices, but did not detect a linear pattern in sales prices with distance from the wind farm. Moreover, closer inspection and conversations with realtors revealed other local conditions that might have exerted negative effects on sales prices during the study period. The authors concluded that variables not included in the analysis may have been the main drivers of sales prices in region, rather than the wind turbines. Sims *et al.* (2008) later employed a hedonic sales model to analyze 201 home sales transactions in the proximity of the 16-turbine wind farm occurring between 2000 and 2007. The authors found no evidence that home sales prices were related to the number of wind turbines visible from each property or to the distance between each property from the wind farm.

Hoen (2006), in a Master's Thesis at Bard College, performed a hedonic pricing analysis using 280 arms-length single-family residential sales occurring between 1996 and 2005 within 5 miles (8 km) of a 20-turbine (30 MW) wind farm in Madison County, New York. The variable of

[8] An arm's length transaction is one in which the buyers and sellers act independently and have no relationship to each other (http://www.realtor.com/blogs/2010/04/21/what-is-an-arms-length-transaction).

interest in that study was turbine visibility, and the author made site visits to each property to determine the degree to which turbines were visible within a property's viewshed. The study failed to detect measurable effects resulting from wind farm visibility on property transaction values in the radius of study, even when concentrating on homes within one mile of the facility.

In a subsequent larger study, Hoen and his colleagues at the Lawrence Berkeley National Laboratory performed a hedonic pricing analysis using data on almost 7,500 home sales within 10 miles (16 km) of 24 existing wind facilities in nine different U.S. states (Hoen *et al.* 2009). Facilities in the study sample ranged from 7 to 582 turbines each and produced 12 - 429 MW apiece. The authors tested the relationship between wind farms and property values through eight variations on a hedonic pricing modal, as well as a repeat sales analysis and a sales volume analysis.[9] The authors found a lack of evidence to support consistent, measurable, and statistically significant relationships between home sales prices and (1) views of wind turbines or (2) distance to wind turbines (Hoen *et al.* 2009). The authors concluded that if such impacts exist at all, they are "either too small and/or too infrequent to result in any widespread, statistically observable impact (Hoen *et al.* 2009: iii)." Because of its large sample size and use of multiple models, this study is often considered to be the seminal work in hedonic pricing analysis of the relationship between wind energy projects and home property values (e.g., Carter 2011).

In sum, most hedonic pricing analyses, and most statistical, market-based analyses in general, have failed to find evidence for the hypothesis that wind energy projects negatively affect the sales prices of nearby homes. However, evidence has recently begun to emerge suggesting that the *announcement* of a proposed or approved wind energy project can have a temporary negative effect on home sales prices. Hinman (2010), in a Master's Thesis project at Illinois State University, found evidence to suggest that property values may be affected more by the apprehension occurring prior to wind turbine construction than by the turbines themselves once constructed. Hinman evaluated 3,851 home sales between 2001 and 2009 near a 240-turbine wind farm in Illinois, to measure whether proximity to the wind farm had any effect on local property values. The author found evidence of a "wind farm anticipation stigma", wherein property values declined after announcement of the wind energy project but prior to construction of turbines, due to "fear of the unknown". That study also found that after construction, property values rebounded and even soared, presumably because residents became accustomed to living near wind turbines (Hinman 2010).

Hoen *et al*. (2011) subsequently reanalyzed the same data used in their 2009 study, employing additional models to further illuminate potential relationships between wind turbines and property values. The results of these models echoed those of their previous study: a lack of evidence of post-construction effects on home sales prices based on either distance from turbines

[9] Sales volume analyses examine the percentage of homes fitting certain (e.g., square footage, number of levels, zoning, etc) that sold during the study period. The relationship between sales volume and wind turbine effects on property values can be explored by comparing sales volumes at varying distances from a wind energy facility and before/after the facility was installed.

or view of turbines. In this study, however, the authors detected some evidence of post-announcement, pre-construction property values effects that appeared to fade after turbine operation. This finding echoes Hinman's (2010) detection of a wind energy project "anticipation stigma" affecting neighborhoods during the project planning phase.

A third study analyzing the effects of wind farm anticipation stigma on home sales prices failed to corroborate this pattern. Laposa and Mueller (2010) used a hedonic pricing model to test for anticipation stigma effects on homes sales with various degrees of proximity to the proposed Maxwell Ranch wind farm in Colorado taking place between 2000 and 2008. The wind farm proposal was announced on March 1, 2007. The authors compared a total of 2,910 property sales, subdivided into those involving properties located in homeowners' associations adjacent to the proposed wind farm, properties located in the same census tract as the proposed wind farm, and properties located in another nearby census tract (with homes up to 50 miles away from the proposed wind farm); 83% of the sales analyzed took place prior to the announcement of the proposed wind farm. The authors detected an overall decline in home sales prices in all three areas around the time of the wind farm announcement (statistically significant at the 10% level); however, this decline was not significant in the area closest to the proposed wind farm. Moreover, the authors caution that the announcement of the wind farm coincided with a steep downward trend in the national housing market, so any correlation between the wind farm announcement and a decline in nearby home sales prices is likely to be spurious.

While most hedonic pricing models have failed to substantiate claims that wind energy projects negatively affect home sales prices, there are at least two exceptions. Each of these two recent studies examined several localities near wind farms. While they detected evidence for significant negative effects on home sales prices related to the presence of wind turbines in some localities, they found no such evidence in others, prompting them to suggest that property values effects of wind turbines can be highly localized, and mediated by geographically variable factors other than proximity to turbines.

The first of these studies was conducted by two researchers at Clarkson University (Heintzelman and Tuttle 2012) and included 11,331 property transactions taking place from 2000 to 2009 in three counties in Northern New York. The authors researched the effects of six wind farms (containing 14-194 turbines and producing 80-320 MW each) in three counties (Lewis, Clinton, and Franklin). They employed a hedonic pricing model with a spatial fixed effects analysis, which controls for geographically determined differences among home sales prices, as well as a repeat sales analysis. In contrast to the majority of sales prices studies, their results suggest that the presence of wind facilities can reduce property values in the surrounding areas in significant ways. In two of the three counties studied (Clinton and Franklin Counties), proximity to wind turbines had a usually negative and often significant impact on home sales prices, and impacts were correspondingly greater with increased proximity to turbines. The repeat sales analysis suggested that sales prices declined by 8.8-14.5% and 9.6-15.8%, respectively, in these two counties.[10] In Lewis County, however, sales prices increased after installation of a wind energy project, suggesting that spatial heterogeneity in consumer preferences or other factors plays a strong role in determining the effects of turbines on property values.

Further evidence for a high degree of spatial variability in wind turbine property values effects is provided by a study performed at the Aachen University in Germany (Sunak and Madlener 2012). These authors explored the impacts of a nine-turbine (13.5 MW) wind farm in the semi-urban state of North Rhine-Westphalia through a geographically weighted hedonic pricing analysis, an exploratory technique enabling investigation of spatial differences within a set of variables. Researchers analyzed 1,202 sales of land parcels in the years before announcement, during construction, and during operation of the wind farm, taking place 945m-5,555m (0.59-3.45 miles) from the wind farm site. This study found some evidence for localized negative effects of proximity to the wind farm site. The geographically weighted model suggested that these effects were not even, but were instead greater in some towns than in others. The authors conclude that further investigation of wind-farm-related impacts focusing on local or even micro-scale effects is needed.

Hedonic pricing models are useful only for detecting broad-scale trends in sales *prices*. Since it is not possible to quantify transactions that don't occur, hedonic analyses do not account for potential instances in which a wind energy facility could diminish the value of a property so much that the property became unsellable. This caveat can lead some observers to question the results of hedonic pricing models that find no evidence for negative effects of wind energy projects on property values (e.g., RESP stakeholder workshop, September 20, 2012). Sales volume is an important variable in its own right, but may be difficult to interpret. High sales volumes in an area near a wind energy project could potentially indicate a heightened desire on the part of current residents to move away from a source of disamenity; on the other hand, low sales in the area would be expected to result from a lack of desire on the part of new residents to move into an area. Hedonic studies also ignore the amount of time that a property is on the market, which can be an important indicator of property values. While sales volume analyses and time-on-the-market analyses would provide valuable complements to hedonic pricing studies on the effects of wind energy facilities on property values, very few have been conducted to date.

One of the few instances in which a sales volume analysis has been applied to understand the potential impacts of wind energy project on property values is Hoen *et al.*'s (2009) analysis, which evaluated sales volumes as a secondary interpretation of the data set that they used for their hedonic pricing model. This study found that the homes located at distances of 1-5 miles (1.6-8 km) from turbines experienced a significant increase in sales volumes after turbines were

[10] The upper and lower bounds to these ranges are correlated with a home's original distance to a turbine, prior to installation of a second turbine in closer proximity to the home that took place between sales.

installed compared to homes further away. However, no significant differences were detected for homes within one mile (1.6 km) of a turbine. Since greater effects on sales volume would be expected in close proximity (e.g., within one mile) to a turbine, the authors conclude that their findings do not support the conclusion that wind turbines exert an effect on sales volume.

Market studies are often considered to be the most authoritative source of information regarding the property values effects of wind energy projects because their methods rely on large samples and advanced statistics. When assigning relative credibility to the studies presented here, however, many observers also recommend considering the authority of the source. It may be of interest to note that of the fifteen analyses presented in this section, only five (Heintzelman and Tuttle 2012; Hoen *et al.* 2011; Laposa and Mueller 2010; Sims and Dent 2007; Sims *et al.* 2008) have been published in peer-reviewed journals, meeting the highest benchmark for objectivity and scientific rigor. Another (Hoen *et al.* 2009) was performed by a government agency, two (Hoen 2006; Hinman 2010) were conducted by graduate students, two (Sim and Dent 2007b; Sunak and Madlener 2012) were conducted by a university department, two (Sterzinger *et al.* 2003; Canning and Simmons 2010) were commissioned by pro-wind energy non-governmental organizations, two (Magnusson and Gittell 2012; Poletti 2007) were commissioned by wind energy developers, and one (Kielisch 2009) was commissioned by a concerned citizens group. This chapter has not ranked analyses based on their source, but simply presents a wide range of information gleaned from the debate about the property values effects of wind energy; decision makers can apply their own rankings to this information as they see fit.

Expert opinion

Because realtors, appraisers, and tax assessors deal with property values on a daily basis, they are often considered experts on possible property values effects of wind energy projects. Over time, these professionals may amass a nuanced understanding of the variables that determine local property values and sales prices. Several studies of the relationship between wind energy facilities and property values have sought to tap the knowledge of these individuals through expert opinion surveys. These surveys show mixed results. As a side note, only some of the respondents interviewed in the three studies presented here had personal experience dealing with homes near wind energy facilities; for those respondents who did not have this kind of experience, opinions about predicted effects of wind energy projects on property values may be analogous to “wind farm anticipation stigma” (*sensu* Hinman 2010), owing to the novelty of wind energy projects for these respondents.

Grover (2002) conducted a phone survey of tax assessors for 13 counties throughout the U.S. containing a total of 22 wind energy facilities (22-342 turbines per facility). Researchers asked tax assessors from each county to talk about the ways in which they think proximity to turbines affects property values. The study found no evidence to suggest that tax assessors perceive a link between proximity to wind turbines and home property values. In addition, six participating tax assessors reported that homes in their counties were within the viewshed of wind turbines, but these assessors did not feel that the homes had suffered a decline in value as a result of these views.

Khatri (2004) conducted a mail survey which was returned by 405 licensed surveyors in the U.K. About 80 of the respondents reported having some experience with residential transactions near wind farms. When asked about the property values effects of wind energy facilities, 60% of the sample expressed the opinion that wind farms decrease the value of residential properties within the viewshed, and 67% indicated that this negative impact begins to occur during the wind energy project planning process, before construction (i.e., anticipation stigma). Respondents also expressed the opinion that once a wind farm is completed, the negative impact on property values persists but becomes less severe about two years after construction. When asked about agricultural land, 28% of respondents felt that it tends to be negatively influenced by wind farm development, 63% felt that there is no impact, and 9% suggested a positive impact. Based on these findings, the author concluded that wind energy development does not affect property values in a uniform way.

Appraisal Group One (Kielisch 2009) surveyed 34 real estate agents, 18 real estate brokers, 2 appraisers, and 3 land developers. The survey asked respondents to compare the expected effects of hypothetical a 1.5-MW wind turbine on the sales prices of properties located at 600ft (183 m), 1,000 feet (305 m), and 0.5 miles (805 m). In all cases, wind turbines were assumed to be visible from the property, and photographs were shown to respondents to illustrate a uniform hypothetical level of visibility. Realtors were asked both whether or not they believed that the hypothetical turbine would exert negative effects on local property values, and how great such an effect would probably be, in terms of percentage decline. The study asked about three land use types (vacant residential, improved residential, and hobby farm). Results showed that over 60% of respondents believed that the presence of the wind turbines would exert a negative impact on property values overall (this number rises to 82% when only vacant residential plots are considered). Properties at 600 ft (183 m) from a turbine were usually expected to have the greatest drop in property values, averaging an estimated decline of -43% for 1-5 acre vacant land and -39% for improved properties. This category was followed by properties at 1,000 ft (305 m) from a turbine (-36% estimated value loss for 1-5 acre vacant land and -33% for improved property) and lastly by properties 0.5 miles (805 m) from a turbine (-29% estimated value loss for a 1-5 acre vacant parcel and -24% loss in value for improved parcels), suggesting that on the whole, respondents anticipated a decline in property values for properties at closer proximities to the hypothetical turbine.

The studies by Grover (2002), Khatri (2004), and Kielisch (2009) relied on standard survey methodology, and their results are based on analysis of the expressed opinions of multiple property values professionals. Another category of expert opinion includes the personal opinions issued by individual appraisers relying on their own experience to express independent opinions about the relationship between wind energy projects and property values. These include the opinions expressed by Gardner (2009) and McCann (2010, 2012). These documents do not always cite their methods and appear to rely on a sample consisting of a single expert, but they are often cited by concerned citizens and wind energy project opponents as evidence for a negative impact of wind energy projects on home property values.

Gardner Appraisal Group Inc. (2009), relying on in-house experience, estimated that properties on which wind turbines are located can be expected to decline in value by an average of 37%, properties located 0.2-0.4 miles (0.3-0.6 km) from the nearest turbine can be expected to decline in value by an average of 26%, and properties 1.8 miles (2.9 km) or less from the nearest turbine can be expected to decline by an average or 15%. Gardner Appraisal Group, Inc. also estimates that an additional 15% - 25% decline in property values can occur as a result of associated wind turbine infrastructure, such as high voltage power lines, additional traffic, and new roads. The empirical basis for these estimates is unclear. In addition, it is not clear whether these estimates apply to wind farms or single turbines.

McCann (2010, 2012) is a real estate valuation advisor who specializes in predicting the impacts on property values that may result from wind energy projects. Relying on a combination of his own judgment and studies by others, McCann has estimated that wind energy projects can result in a 25-40% decrease in property values for properties up to two miles from wind turbines (2010). The empirical basis for these estimates is unclear. McCann (2012) has also reported incidents in which time on the market appeared to increase as a result of wind energy projects, and where home abandonment had occurred as a result of the nuisance caused by a wind energy project. As in the previous expert-based example, it is not clear whether these estimates apply to wind farms or single turbines, or how these estimates may vary based on population density of the surrounding area.

Anecdotal accounts

Anecdotal accounts are "observations or studies, which do not provide proof but may assist research efforts" (www.dictionary.com). Because anecdotal accounts are drawn from very small sample sizes – the individual or local group – they cannot be generalized to larger scales. Nonetheless, they can provide value: according to Moore and Stilgoe (2009), anecdotal evidence includes "the knowledge of specific, local conditions, including social conditions, that are not, and indeed cannot be accounted for in general assessments of risk based on 'typical' circumstances….knowledge of these particular social conditions must come from the people most intimately involved." For instance, anecdotal information can point to types of evidence that cannot be readily evaluated statistically due to the absence of a sufficiently large sample size, but that can shed light on lingering questions and provide directions for further study. Anecdotal information is also helpful at identifying specific cases that diverge from the generalities described by larger-scale studies, and understanding the potential causes for this divergence.

The following list presents several anecdotal accounts from around the U.S. and Canada that assert a perceived link between the existence of wind turbines and a change in home property values for at least some homes in the vicinity of turbines. In contrast to the market research data examine previously in this chapter, anecdotal accounts such as those presented here are qualitative and case-specific. As such, they are not subject to peer review, cannot be assumed to represent broad-scale trends, and do not employ statistical methods to distinguish the influence of wind turbines from other trends affecting home values. However, these accounts can add contextual nuance to the emerging understanding of the impacts of wind turbines on property values and can inform avenues for future research.

These accounts were culled through an internet search using the following three criteria: (1) attributable to a specific source; (2) referencing a specific place and time; and (3) hypothesizing a specific negative cause-effect relationship between wind turbines and property values. Although diverse anecdotal accounts have asserted negative, positive, and neutral effects of wind energy projects on property values, it is considerably easier to locate claims of a negative nature due to their widespread dissemination by concerned citizens and opponents of wind energy facilities. Anecdotal evidence supporting a positive or neutral relationship between wind energy facilities and property values is likely to be underrepresented due to its non-controversial nature. The validity of the following claims is neither questioned nor confirmed; these accounts are simply replicated here to indicate the range of anecdotal evidence that is presently framing debates about the property values impacts of wind energy projects.

- *Falmouth, MA:* Annie Hart Cool, a Sotheby's realtor living 0.5 miles (0.8 km) from a 1.65MW turbine says that she experienced a drop in business and a reduced property value appraisal of her own home, which she attributes to the turbine. Based on her experience as a realtor, she also asserts that homeowners must reveal any proposed industrial wind turbines in the vicinity of their home as a Negative Material Fact when selling a home. [The source of this account is a 2012 opinion piece on Wind Turbine Syndrome, a website critical of the impacts of wind energy facilities.[11]]
- *Shelburne Falls, MA:* Vicki Citron of Newton, MA submitted a letter to the editor of the Shelburne Falls & West County Independent of Nov. 11, 2011, saying that she opted not to purchase land two miles from a then-proposed 20 MW windfarm, expressing the opinion that, "We don't want to live near this industrial site with the health hazards and lowering of property values associated with it." [The source of this account is a 2011 opinion piece on Wind Turbine Syndrome, a website critical of the impacts of wind energy facilities.[12]]
- *Fairhaven, MA:* Attorney Ann DeNardis, representing homeowners who filed for an emergency halt to construction of two 1.5-MW turbines in Fairhaven, MA, says that she has observed signs of decline in nearby property values resulting from construction of the two

[11] www.windturbinesyndrome.com/2012/wind-turbines-constitute-a-taking-of-private-property-value-mass
[12] www.windturbinesyndrome.com/2012/wind-turbines-constitute-a-taking-of-private-property-value-mass

turbines. Property values were only one of the issues of concern that was cited in the motion. [The source of this account is a 2011 article in South Coast Today, a local newspaper in Southeastern Massachusetts.[13]]

- *Grand Bend, Ontario*: Doug Pedlar, a real estate broker with ReMax in Grand Bend, Ontario, asserted that the value homes within view of rotating turbine blades take longer to sell than homes without blade visibility, and can sell for 30% less than market value. He cited three incidents where homeowners near wind turbines experienced difficulty selling their homes or sold them for much less than the asking price. [It is unclear whether these instances involved wind farms, single turbines, or both. The source of this account is a 2012 article in Sarnia This Week, a local newspaper in Sarnia, Ontario.[14]]
- *Melancthon-Amaranth, Ontario:* Realtor Chris Luxemburger declared that homes near a 133-turbine wind farm in the Melancthon-Amaranth area in Ontario were selling for less and taking longer to sell than the homes located further away, and that properties directly adjacent to the wind farm sold for 20-40% less than comparable properties out of sight of the turbines. [The source of this account is a 2011 article from CBC News Network, Canada.[15]]
- *Ontario:* A local bank in Ontario is not allowing lines of credit to be secured by certain houses situated near wind turbines. In a letter to a prospective borrower living near a facility, the bank wrote, "we find your property a high risk and its future marketability may be jeopardized." [It is not clear whether this letter refers to wind farms, single wind turbines, or both. The source of this account is a 2011 article from CBC News Network, Canada.[16]]
- *Brownsville, WI:* Ann and Jason Wirtz brought suit against Invenergy LLC after their property, appraised at $320,000 in 2007, sold to the Bank of New York Mellon at a sheriff's sale for $106,740; they named the company's Forward Energy Wind Center as their reason for leaving their home, and demanded to be compensated by the company at the level of the 2007 appraised value of their property. [The Forward Energy Wind Center consists of 86 1.5MW turbines. The source of this account is a 2010 article in The Daily Reporter, a Wisconsin construction industry newspaper.[17]]
- *Wolfe Island, Ontario:* Ed and Gail Kenney challenged an assessment of the value of their property, located near an 86-turbine wind farm, claiming that the wind farm had reduced the value of their property below what was reported in the assessment, which increased the estimated value of their home from $200,000 in 2008 to $357,000 in 2010. The tax assessment board concluded that property values on the island had not dropped because of wind turbines in the area, and refused to lower the assessed value of the Kenney's property. The source of this account is a 2012 article in The County Weekly News, a local newspaper covering Picton County, Ontario.[18]
- *Lincoln, WI:* Joe Jerabek, Town of Lincoln, WI zoning administrator, compiled a list of home sales at varying distances from a 22-turbine wind farm showing that sales values within one mile (1.6 km) of the wind farm declined from 104% of assessed value (prior to wind farm installation) to 78% of assessed value (after wind farm installation), and that sales values outside of 1 mile (1.6 km) of the wind farm declined from 105% of assessed value (prior to wind farm installation) to 87% of assessed value (subsequent to wind farm installation). [The

---

[13] www.southcoasttoday.com/apps/pbcs.dll/article?AID=/20120105/PUB01/201050364/1039
[14] www.sarniathisweek.com/2012/02/28/wind-turbines-blow-down-resale-value-of-homes-pedlar
[15] www.cbc.ca/news/canada/ottawa/story/2011/09/30/ontario-wind-power-property-values.html
[16] www.cbc.ca/news/canada/ottawa/story/2011/09/30/ontario-wind-power-property-values.html
[17] http://dailyreporter.com/2010/05/06/wind-farm-property-sells-at-sheriffs-sale/
[18] www.myvirtualpaper.com/doc/Picton-County-News/picton/2012041101/52.html#52

source of this account is Wind Farm Realities, a website critical of the impacts of wind energy facilities.[19]]

- *West Prince, Prince Edward Island:* A spokesperson with the tax department of West Prince, Prince Edward Island, said a handful of residents living next to wind farms had received lower property value assessments, and that although the criteria for assessing property values doesn't specify turbines, the department felt the properties near windmills should be treated the same as properties near industrial areas. [The source of this account is a 2008 article in from CBC News Network, Canada.[20]]
- *Jefferson County, NY:* Amanda J. Miller of Lake Ontario Realty in Dexter, NY reported to the Jefferson County Board of Legislators that she has had clients pull out of deals and refuse to consider areas where future wind energy development may be considered. “People do not want to buy near windmills,” she said at the meeting. “They avoid purchasing in towns like Cape Vincent [NY]." In a phone interview with the Watertown Times, Ms. Miller added, "Even if people don't mind looking at it, they're not going to put their investment in an area where they're going to have turbines depreciate it.” [The source of this account is a 2010 article in the Watertown Daily Times, a local newspaper serving Jefferson, St. Lawrence and Lewis counties, New York.[21]]

This review of anecdotal accounts may help municipal decision makers by enabling them to anticipate the types of arguments and challenges they may face during the public process for approval of a wind energy project proposal. It should be noted, however, that like most large-scale research performed to date, most of the anecdotal accounts presented above refer to the impacts of multi-turbine wind farms, not single turbines. While each of these accounts represents an isolated case and, as such, cannot be measured via statistical methods or generalized to other wind energy facilities or neighborhoods, their existence suggests a need to further investigate the influence of wind energy facilities on property values. Even if wind turbines do not exert a global and consistent effect on nearby property values, as suggested by most large-scale studies, there may be certain conditions under which an impact occurs. These conditions might include excessive noise or shadow flicker, proximity to scenic or historical settings, and other factors. The literature to date on property values impacts has focused largely on whether property values impacts occur, and has not delved deeply into these more siting-specific questions. Identifying any such conditions is key to minimizing these effects in future wind energy projects.

Several of the accounts above demonstrate “wind farm anticipation stigma”. Instances where prospective buyers decline to purchase homes due to apprehension over the effects of a nearby wind energy project, and where existing homeowners oppose proposed wind energy projects due to apprehension of their potential effect on their home values, can both be considered to reflect “anticipation stigma”. The degree to which anticipation of possible negative effects of wind energy projects on property values is actually reflected in these values represents an avenue for future research.

[19] http://windfarmrealities.org/wfr-docs/lincolntownship.pdf
[20] www.cbc.ca/news/canada/prince-edward-island/story/2008/12/23/pe-wind-assessment.html
[21] http://www.watertowndailytimes.com/article/20100407/NEWS03/304079990

The RESP stakeholder process included a presentation by two Portsmouth residents, in which they presented anecdotal information regarding the effects of a wind energy project on the value their property. Donna and Tony Olszewski, who own a home 750 ft (229 m) from the 1.5 MW wind turbine at the Portsmouth, RI high school, say that the value of their home has been greatly impacted and that their real estate agent said that she would not be able to sell their home (Haas 2012; Olszewski and Olszewski 2012). Around the time of the RESP stakeholder meeting in January 2012, the Olszewskis requested an exemption from paying property taxes due to their perception that the value of their home has been decimated by noise and shadow flicker issues. The Portsmouth Tax Assessment Board of Review concluded that this was not within their purview.[22] Anecdotal accounts taking place in Rhode Island are undoubtedly more relevant to understanding potential impacts in the state than accounts involving large-scale wind energy projects in other regions of the country. Future research is needed to assess the experiences of the Olszewskis and other homeowners living near existing and future wind energy projects in the state.

Additional research needs

As the discussion above illustrates, the effect of wind turbines on property values can be difficult to isolate. An apparent disconnect exists between the majority of market data studies, which for the most part fail to find a significant relationship between wind energy projects and nearby property values, and the existence of many anecdotal accounts asserting that a negative relationship exists, albeit on a case by case basis. Anecdotal reports should be considered in order to grasp the entirety of this complex issue, even if those accounts are not substantiated by large-scale analyses.

Thus far, large-scale analyses have focused primarily on the question of *whether* wind energy projects affect property values, and have made less of an effort to detect the conditions under which such an impact may be most or least likely to occur. Although several studies use distance as a proxy for noise, shadow flicker, and visual impacts (e.g., Hoen *et al.* 2009), they rarely address these intervening variables directly (an exception is Hoen 2006, which empirically measured the visibility of turbines from each residence). In contemplating siting guidance for wind energy projects, it may be valuable to further consider how geography, cultural attitudes, land use, preexisting property values, number of turbines, height of turbines, and turbine technology shape the effects of each individual wind energy project on nearby property values. It is also important to gain a greater understanding of why property values impacts occur, if and when they do (e.g., noise, shadow flicker, visual impacts, or some other cause); this information is vital to creating mechanisms that mitigate these concerns and assure that future projects do not negatively affect property values.

[22] http://www.portsmouthri.com/boards/taxbdofreview/minutes/01-10-12TABR.pdf

Market sales studies are generally considered to be the best available science on the relationship between wind turbines and property values, because they draw on statistical analysis and large sample sizes. However, in looking at the big picture, large-scale studies can potentially miss micro-scale variables that could ultimately have a large effect on this relationship in certain areas or contexts. Specifically relevant to the Rhode Island context, two areas of inquiry have been largely missing from large-scale analysis to date: (1) property values effects of single-turbine wind energy facilities, and (2) property values effects within very short distances of wind energy facilities. Both of these areas may have particular relevance for predicting property values impacts in Rhode Island, due to the state's high density of homes and limited available open space.

Ch. 1 Table 14 demonstrates the primacy of large-scale wind energy projects in market sales research to date by summarizing the data sets used in six hedonic pricing model studies.[23] As this table demonstrates, existing large scale studies have predominately focused on multi-turbine wind farms in rural states where population densities tend to be lower than in Rhode Island. In Rhode Island, the largest wind energy facility consists of three turbines (Narragansett Bay Commission facility) and all other facilities in the state at the time of this publication consist of single turbines (see

Ch. 1 Table 15). The studies in Table 14 range from 4-429MW facilities, while Rhode Island's existing facilities range from 1-4.5MW (see Table 15). Despite Sterzinger *et al.*'s (2003) suggest that large multi-turbine wind farms are likely to have more pronounced effects on property values than small facilities, if indeed an effect exists, it can also be argued that since wind farms are much less likely than single-turbine facilities to be located in densely populated areas, their impacts may in fact be lower than those or single-turbine facilities. Further study is required to delineate possible differences in the likelihood of impact between multi-turbine wind farms and smaller facilities.

In addition, large-scale market sales studies have rarely focused in on properties within short distances from wind energy projects. As Table 14 indicates, most data sets used in large-scale market sales studies to date have considered few homes in very close ranges to the turbines, and when they do include homes within ½ mile (0.8 km) from turbines, they group these homes together rather than testing for differences within this group. This omission is in part due to geometry: since the area within a circle expands as its radius grows, the available space for houses becomes much greater as one looks further from a turbine. But this gap is also an artifact of the current emphasis on studying multi-turbine wind farms rather than single-turbine installations, since wind farms are usually located in rural areas where homes are located at greater distances due to low population density. Since several existing Rhode Island turbines are located at less than 1,000 feet from residential properties (see Table 15), differences among the

[23] These six studies were selected for inclusion in this table because they are the only studies reviewed in this chapter for which all descriptors – number of sales, number of facilities, number of turbines, facility size, location, and distance from turbines to properties sold – were reported.

selling prices of homes within short distances of wind energy projects are may be an important variable to consider when improving our understanding of potential impacts in the state.

The case for studying impacts at smaller distances from turbines has been made by Hoen *et al.* (2009), who wrote that "[t]he primary goal of subsequent research should be to concentrate on those homes located closest to wind facilities" (xvii). Hoen (2006) pointed out that studies of HVTLs have documented that their effects exist only inside 500 ft (152 m; Des-Rosiers, 2002, cited in Hoen 2006), and suggested that "[f]uture studies [of wind power] should find communities with homes closer than 0.75 miles, and preferably as close as 500 feet if they exist" (Hoen 2006: 40-41). The potential for property values impacts to occur within close ranges of wind turbines in ways that diverge from the conclusions of the wind farm-centric literature presented in this chapter is an important factor to consider during siting and to track after a project goes online.

Because of Rhode Island's high population densities, some sense of this relationship may be garnered by examining property values close to the state's existing turbines. However, it should be noted that the majority of turbines located in Rhode Island are on the cusp of being defined as large-scale structures, and it seems unlikely that small facilities (defined for the purposes of the RESP as those less than 100kW) would have any impact on property values. Any study of Rhode Island's existing turbines should bear this size difference in mind, and contextualize any findings within the size range found among existing turbines in the state.

Ch. 1 Table 14. Data sets used in large-scale market analyses of the impacts of wind energy facilities on nearby property values

Study	# of sales	# of facilities	# of turbines	Power output	Location	Distances from turbines to properties transacted
Hoen et al. (2009); Hoen et al. (2011)	7,459	24	7 - 582	12 MW-429 MW	OR, WA, TX, OK, IA, IL, WI, PA, NY	67 sales within 3,000 ft 58 sales between 3,000 ft - 1 mile 2019 sales between 1-3 miles 1923 sales between 3-5 miles 870 sales outside of 5 miles
Hoen (2006)	280	1	20	30 MW	NY	4000 ft - 5 miles; mean of 3.5 miles
Hinman (2010)	3,851	1	240	396 MW	IL	All sales >1,500 ft (developer's self-imposed setback)
Heintzelman and Tuttle (2012)	11,331	6	14 - 194	21 MW – 320 MW	NY	25 sales within 0.5 mile 59 sales between 0.5–1 mile 71 sales between 1–1.5 miles 88 sales between 1.5–2 miles 218 sales between 2–3 miles
Sims and Dent (2007)	919	3	10-16	4 MW – 9.6 MW	UK	53 sales between 0.5–1 mile 2 sales between 1–1.5 miles 61 sales between 1.5–2 miles 134 sales between 2–2.5 miles 72 sales between 2.5–3 miles 64 sales between 3–3.5 miles 40 sales between 3–3.5 miles 393 sales over 4 miles

Ch. 1 Table 15. Characteristics of existing wind energy projects in Rhode Island

Wind energy project	Location	# of turbines	Power output	Distance to nearest house[24]
New England Institute of Technology	Warwick	1	100 kW	1,730 ft (527 m)
Shalom Housing, Inc.	Warwick	1	100 kW	543 ft (166 m)
Fishermen's Memorial State Park	Narragansett	1	100 kW	356 ft (109 m)
Portsmouth High School	Portsmouth	1	1.5 MW	492 ft (150 m)
Portsmouth Abbey	Portsmouth	1	660 kW	617 ft (188 m)
Middletown Corporate Park	Middletown	1	100 kW	1,395 ft (425 m)
Hodges Badge	Portsmouth	1	250 kW	
Wind Energy Development LLC	North Kingstown	1	1.5 MW	
Narragansett Bay Commission	Providence	3	4.5 MW	1,017 ft (310 m)
Sandywoods Farm	Tiverton	1	275 kW	287 ft (87 m)

[24] Data on the distances between existing turbines and nearest houses were assembled using Google Maps. Every effort was made to assure that the structure considered to be the nearest house was in fact a residence and not a commercial building. Participating properties were excluded.

Mitigation of property values impacts through monetary compensation

Monetary compensation of nearby homeowners by wind energy project developers may present one way to overcome concerns about the negative impacts of wind turbines on property values. This type of compensation is a relatively new occurrence, but draws upon a larger tradition of compensatory schemes for locally undesirable land uses (LULUs), a category that includes highways, airports, homeless shelters, and landfills – uses which, like wind turbines, provide broad public benefits to many but impose localized costs on a few nearby residents (Been 1993).

Compensation may take several forms. Under a neighbor agreement, a wind energy developer agrees to pay a specific sum to residents within a specified distance from a proposed turbine for a specific amount of time, as a means of compensating those residents for potential negative impacts exerted by the wind facility on property values. In a property value guarantee, a developer agrees to compensate homeowners for any difference occurring between expected sales prices and the actual amounts that homes are sold for. A third option is for wind energy developers to agree to purchase homes in the vicinity of a proposed facility in the event that current owners choose to move out of the area.

Because compensation agreements are often not publicized, it can difficult to gauge how frequently they occur or how effective they have been. The RESP found several examples of established and proposed compensation agreements. Some were voluntary and others were required by legislation or ordinances.

- *Madison County, New York*: Canastota Windpower LLC, which operates the 30-MW Fenner Wind Project in New York, offered a Property Value Assurance Plan in April 2001. This was a voluntary agreement designed to "protect the immediate neighbors of the wind farm from the remote possibility that the value of their owner-occupied property will be diminished." The agreement specifies that two real estate agents shall be asked to estimate the value of participating homes prior to construction of the wind farm (baseline value), which shall be updated by a third realtor if the home goes on the market within a three-year window beginning in June 2001. The agreement obligates Canastota Windpower to compensate the owners of any home that remains on the market for at least 18 months and sells for less than the updated estimate, by paying the difference between the updated estimate and the actual selling price. According to the agreement, Canastota Windpower also reserves the right to purchase any participating property at the updated market price.[25]
- *Ellis County, Kansas*: In 2007, Iberdrola offered a neighbor agreement to property owners in the vicinity of its Hays Wind Project in Ellis County, Kansas. Property owners were offered three versions of this agreement. In one, the company promised to pay $3000 to each signatory within 30 days of the commencement of construction on the project. In the other two, the company promised to reimburse eligible property owners through free energy usage of up to 10,000KW or 20,000 KW per year, depending on the agreement offered, for up to 35 years or the life of the project, whichever comes first. In return, participating parties agreed to grant the company a noise easement and a light and shadow easement allowing heightened

[25] http://www.windaction.org/documents/4898

levels of noise, shadow flicker, and lighting effects on their properties. The closest residence to the Hays Wind Project, as laid out in the agreement, is 2,000 ft (610 m), and the area surrounding the wind farm is rural.[26]

- *DeKalb County, Illinois*: DeKalb County conditioned an ordinance granting a special use permit to FPL Energy Illinois Wind, LLC for a 119-turbine wind farm, on a requirement that the wind energy developer offer a property value guarantee agreement to owners of any property situated within 0.75 miles (1.2 km) from any part of the facility. The agreement states "that if the Property described herein is sold at a price less than the asking price as a result of proximity to the Wind Energy Center, as determined by the procedures contained herein, the Guarantor will guarantee payment to the Property Owners of such difference." [27]
- *Denmark*: A Danish law enacted in 2008 requires wind energy developers to compensate homeowners for property value losses of over 1% incurred as the result of wind energy projects. Loss in value must be determined by an appraisal authority.[28]
- *Hammond, New York:* The Wind Committee of Hammond, New York drafted a Residential Property Value Guarantee Agreement that would obligate wind energy developers to compensate homeowners for any difference between the asking price and the sales price of a sold property. As drafted, the agreement would apply to any new wind energy projects in the town and would extend to all residences located within 2 miles (3.2 km) of a turbine. Only property owners who owned homes at the time at which developers received a permit from the town are eligible to receive compensation, and sales must take place within five years of the agreement's signing. Asking price must be determined jointly by the developer and the homeowner, with the help of a third-party appraiser if necessary.[29]
- *Maine*: In 2011, the Maine legislature entertained but failed to pass bill LD1042, "An Act To Preserve and Protect Citizens' Property Rights and Values." This bill would have established a statewide property value guarantee program under which wind energy project developers would have been required to extend a property values guarantee to owners of all properties located within 3 miles (4.8 km) of the base of a wind turbine. Developers would have been required to pay the difference between asking price (jointly agreed to by landowner and developer, or assigned by an appraiser) and the actual price received for a property within ten years of signing the agreement.

According to Poletti (2011), several common issues tend to arise when developers and communities deliberate compensation agreements. These include the fact that only homeowners who sell their house benefit, that the agreements can be difficult to administer, that the process involves several appraisals and deadlines, that there can be contention over who is entrusted to hire the appraiser, questions about whether appraisers and realtors are properly informed, and the fact that compensation agreements can negatively affect prices paid for properties outside the project area. On the positive side, Poletti (2011) asserts that compensation agreements

---

[26] docs.wind-watch.org/haysneighboragreement.rtf

[27] DeKalb County ordinance No. 2009-05 and property value guarantee agreement template are available online at: http://www.dekalbcounty.org/planning/FPL/ord2009_05.pdf (Last accessed October 1, 2012).

[28] http://www.ens.dk/en-us/supply/renewable-energy/windpower/onshore-wind-power/loss-of-value-to-real-property/sider/forside.aspx

[29] Residential Property Guarantee Agreement. Available at: http://croh.info/attachments/975_PROPERTY_VALUE_GUARANTEE_AGREEMENT1.pdf

demonstrate a commitment to local homeowners and a conviction on the part of the developer that there will be no impact on property values resulting from a new project. Poletti (2011) also states that compensation agreements facilitate the permitting process by assuring worried homeowners that if an impact occurs, it will not affect them directly.

The only instance of property value compensation known to exist in Rhode Island at the time of this writing is a commitment by developer Mark Pasquale to make monthly payments of $150 to homeowners living in the North Kingstown Green subdivision, where Pasquale's 413-ft turbine was erected in October 2012. This sum is intended to compensate homeowners "for having the turbine in their neighborhood" (Faulkner 2012).

Property values agreements, neighbor payments, and property purchases represent an added expense for the developer, and may have implications for the economic feasibility of a project. This may be especially true in densely populated areas, where there may be many homes located within a small radius of a wind energy project. At the same time, the profits accruing to a single-turbine facility are presumably much less than to a wind farm. While it may in some cases be feasible for large-scale wind farms in rural areas to make neighbor payments, enter into property values agreements, or purchase nearby properties outright, these options may be less feasible for single-turbine facilities located in more densely populated areas like Rhode Island.

In addition, it is unclear how feasible property values compensation agreements are in cases where a wind energy project is owned by a municipality, as opposed to a private developer. Many of Rhode Island's current turbines are owned by municipalities, and this is likely to continue to be the case as more turbines are installed. For municipally owned projects, entering into compensatory agreements with nearby property owners would present a tradeoff between addressing a project's effects on certain property owners and spreading the benefits of a project among all municipal residents (e.g., by using the renewable energy income stream to offset a need to raise taxes). In cases where turbines are municipally owned, a careful siting process is likely to take precedence over compensation agreements as a route to avoiding potential negative property values effects of wind energy projects.

4. Wind Energy Siting

4.1 Siting Analysis

As part of the RESP initiative, a number of tools were developed to aid in the siting and evaluation of potential wind energy projects. The purpose of these tools was not to site projects, rather identify the best sites for development in the state, but to provide a resource for municipalities, potential developers, and residents seeking to understand the potential siting considerations at a given location. In addition, the RESP developed tools to help visualize acoustic and shadow flicker impact zones and evaluate potential setback distances at proposed sites. Each tool allows the user to input specific parameters, based on a particular project. These tools are publicly available online at RI Energy.org.

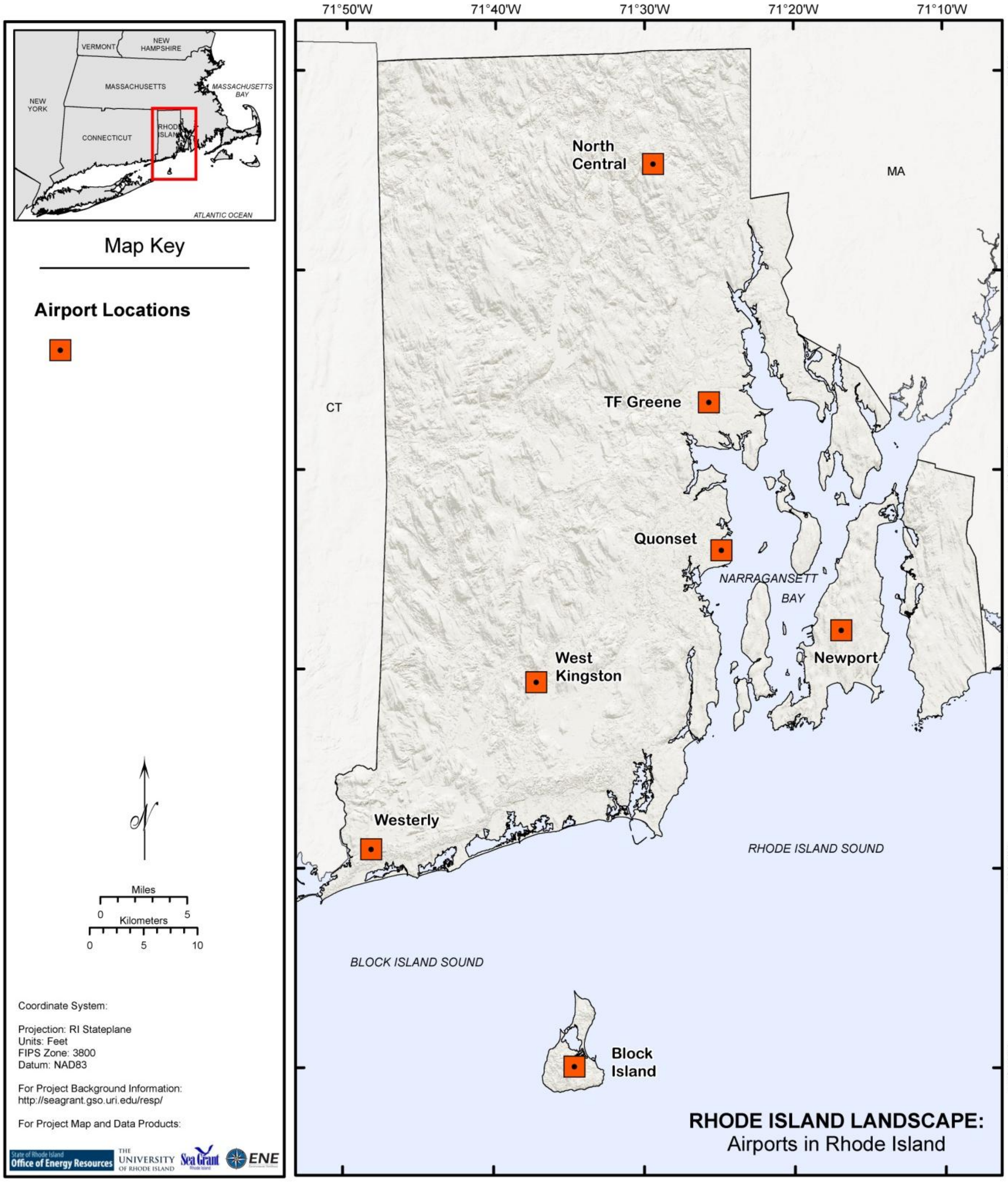
RESP siting tools were developed through compilation of a number of map layers, each one representing a particular aspect relevant to wind turbine siting. Ch. 1 Table 16 contains a complete list of layers used to develop RESP siting tools. The RESP siting tool enables interested parties to visualize these map layers individually or in combination, and to manipulate them in order to view select variables of interest.

Ch. 1 Table 16. Siting Issues and Considerations used in the RESP Siting Analysis.

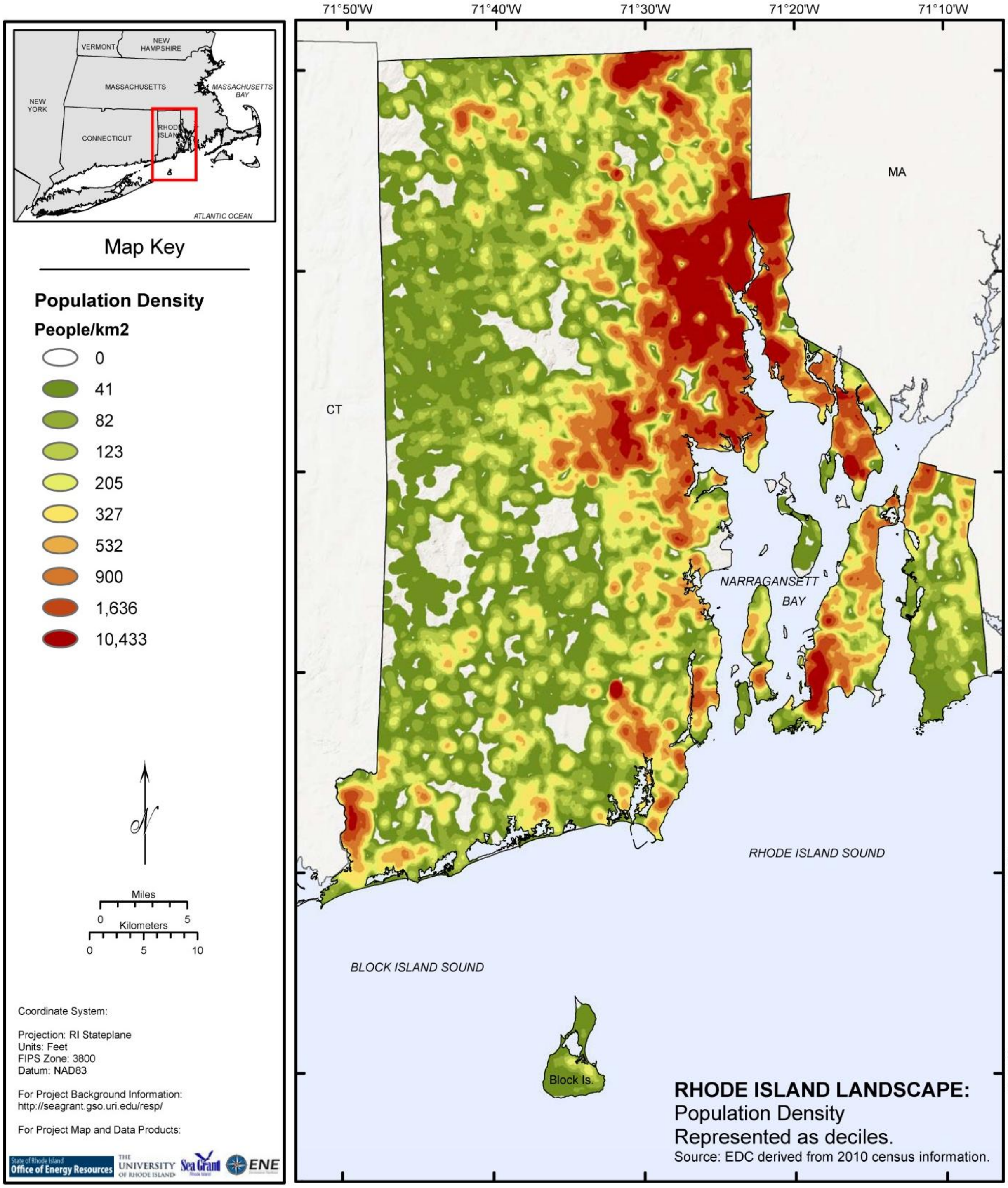
Layer	Siting Consideration/Issue	Description	Data source
Federal Aviation Administration (FAA) restricted areas (Ch. 1 Figure 31)	The Federal Aviation Administration (FAA) requires a setback between airports and any structure measuring over 200 ft (61m). The distance of this setback varies according to the size of the airport. The FAA must be consulted when installing anything over 200 feet.	This layer shows areas where height restrictions associated with the FAA may need to be considered. This layer was created by examining the height restrictions around the following Rhode Island airports: T.F. Green International Airport, Block Island State Airport, Westerly State Airport, Quonset State Airport, North Central State Airport, Newport State Airport, and Richmond Airport.	The FAA provides online siting tools to help determine if an FAA ruling is required for a project (see https://oeaaa.faa.gov/oeaaa/external/portal)
Population Density (**Error! Reference source not found.**)	Residential population density may be an important metric when considering the impacts of wind turbine noise, shadow flicker, safety concerns, and other potential impacts.	This layer represents population density by mapping standard deviations above/below the mean R.I. population density of 1018 people/mile^2. Areas shaded in orange and red represent areas of high population density, which may require additional siting considerations to minimize any impacts to surrounding residents.	Data from U.S. Census 2010; Layer obtained from the Rhode Island Geographic Information System (RIGIS).
Wetlands, with 50-ft (15-m) buffer zones (Ch. 1 Figure 33)	Wetlands are considered a particularly valuable and irreplaceable habitat, and require special consideration in the wind turbine siting process.	This layer shows the location of wetlands (freshwater and coastal) The layer also incorporates a 50 foot (15 meter) buffer around each wetland area, to represent the setback used by RIDEM.	RIDEM

Water bodies, rivers and large streams, with 100 ft (30 m) buffer zones (Ch. 1 Figure 34)	Water bodies represent hard constraints, where wind turbines cannot be sited.	This layer shows the lakes, rivers, and streams that are found throughout Rhode Island, with 100 ft (30m) buffer zones around them.	RIGIS
Impervious surfaces (Ch. 1 Figure 35)	Impervious surfaces may represent hard constraints, where wind turbines cannot be sited, especially when the impervious surface represents a highway or road. In some cases however, wind turbines may be sited on an impervious surface such as a parking lot.	This layer shows highways, roads, parking lots, and other impervious surfaces in Rhode Island.	RIGIS
Conservation lands (Ch. 1 Figure 36)	Development of a wind power facility in or near state, federal, and NGO protected areas may complicate the permitting process, unless the state, federal, or NGO owner/manager of the land is also the developer of the wind facility.	This layer shows state, municipal, and NGO lands designated for protection.	RIGIS
Areas with threatened or endangered avian species, with buffer zones (Ch. 1 Figure 37)	Areas of importance to vulnerable bird populations represent areas where wind energy development may be inappropriate (Paton *et al*. 2012)	This layer shows areas with previous sitings of four threatened or endangered bird species, with the buffers prescribed by Paton et al (2012): ▪ American Oystercatcher (500m; 0.3 miles) ▪ Bald Eagle (1 mile; 1.6km) ▪ Least Tern (1km; 0.6miles) ▪ Roseate Tern (1km; 0.6 miles)	Paton *et al*. (2012)
Bird habitats, with buffers: Grasslands (**Error! Reference source not found.**); Forests; Shrubs	Grassland, forest, and shrubland habitats are important for vulnerable bird species, and some of these habitats are declining in Rhode Island. These habitats represent areas where wind energy development may be deemed inappropriate for conservation reasons (Paton et al. 2012)	These layers show patches of grassland greater in size than 3 acres, with a 100m (328-ft) buffer around each patch; forests greater than 100 acres; and shrub habitat greater than 5 acres, with a 100m(328ft) buffer around each patch.	Paton *et al*. (2012)

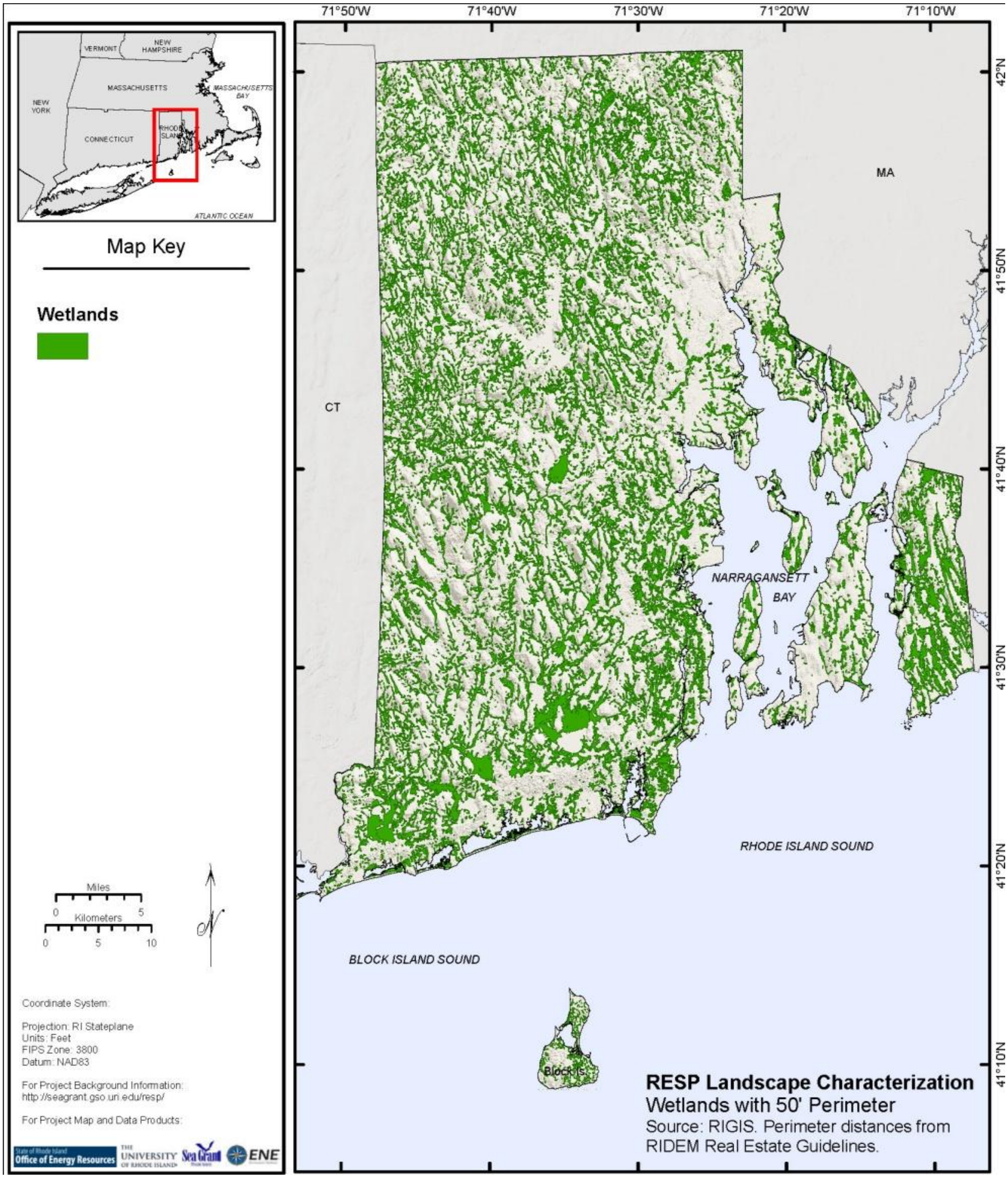
Communication Towers (Ch. 1 Figure 23)	Consideration of the proximity of a proposed wind turbine to existing communication towers may help to minimize any potential interference effects.	This layer shows the current location of all existing communication towers in Rhode Island.	RIGIS
Historical state and federal sites, areas, and cemeteries (Ch. 1 Figure 29)	Rhode Island's historical and cultural areas possess important heritage value, and many are protected by law. These sites and areas represent areas where wind energy development may be inappropriate and/or illegal. Cemeteries should be viewed as a hard constraint where development of wind turbines cannot take place.	This layer shows historic districts and buildings listed in the National Historic Register. In addition, this layer includes a preliminary dataset representing the approximate locations of historical cemeteries registered with the Rhode Island Advisory Commission on Historical Cemeteries.	RIGIS
Ecological Land Units (ELUs) (Ch. 1 Figure 38)	Ecological Land Units (ELUs) represent a biodiversity index that may help to identify areas of special ecological importance that should not be disturbed. ELUs are calculated by counting the number of different habitat types found within a 1,500-m (0.9-mile) radius of each point on the map.	This layer show ELU values across Rhode Island. ELU values were assigned according to a 30x30-meter (98x98ft) grid.	The Nature Conservancy Rhode Island Chapter and Rhode Island Environmental Data Center
Background noise level (land use, highways) (Ch. 1 Figure 39)	Ambient noise plays an important role in the effect of wind turbine noise on the surrounding population. Where ambient noise levels are high, wind turbine noise is less noticeable.	This layer shows modeled ambient noise levels created using land use data and the locations of busy highways to predict sound levels.	Potty and Miller(2012)



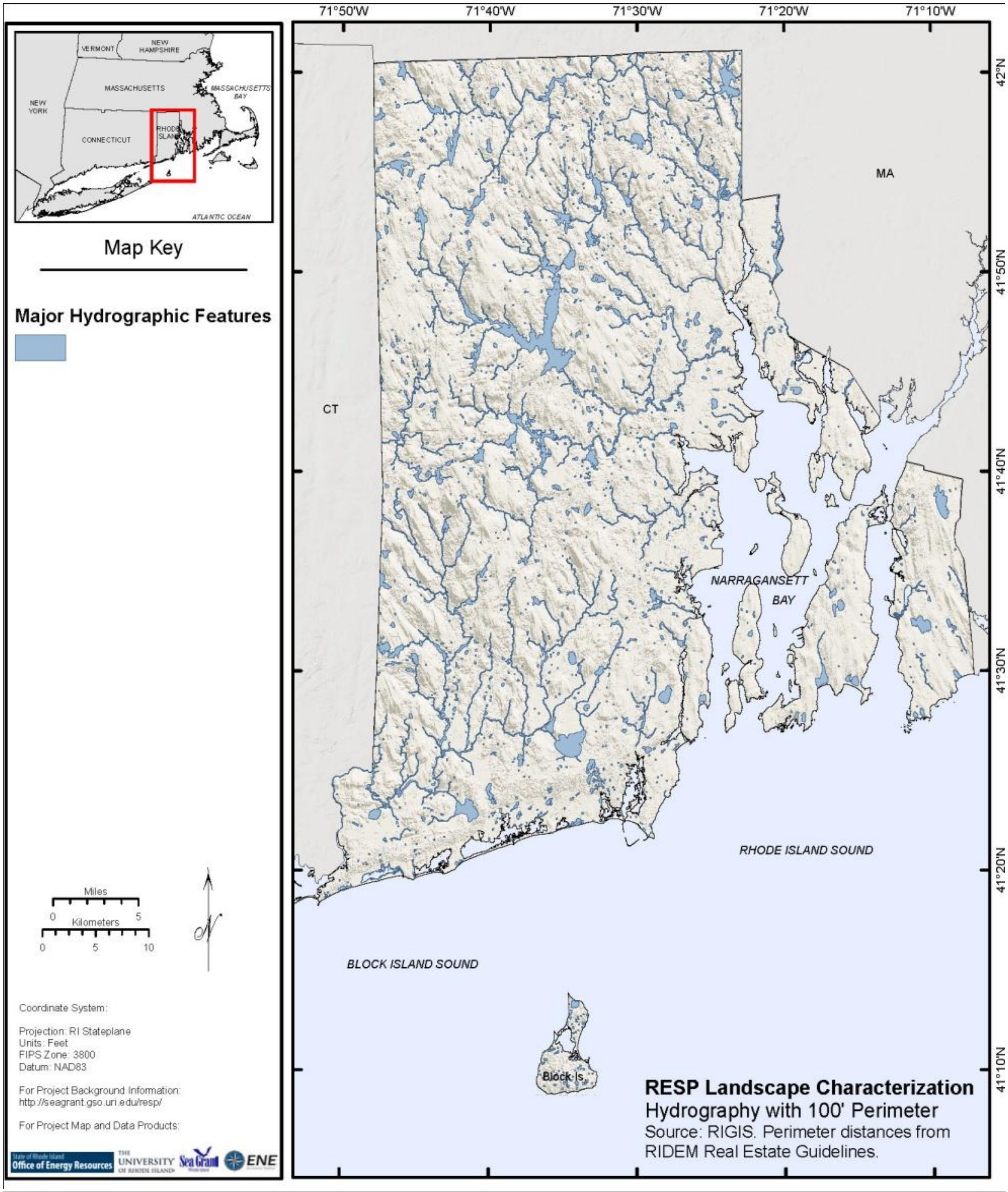
Ch. 1 Figure 31. Rhode Island Airports (Note: the FAA must be consulted before installing any structure over 200 ft).



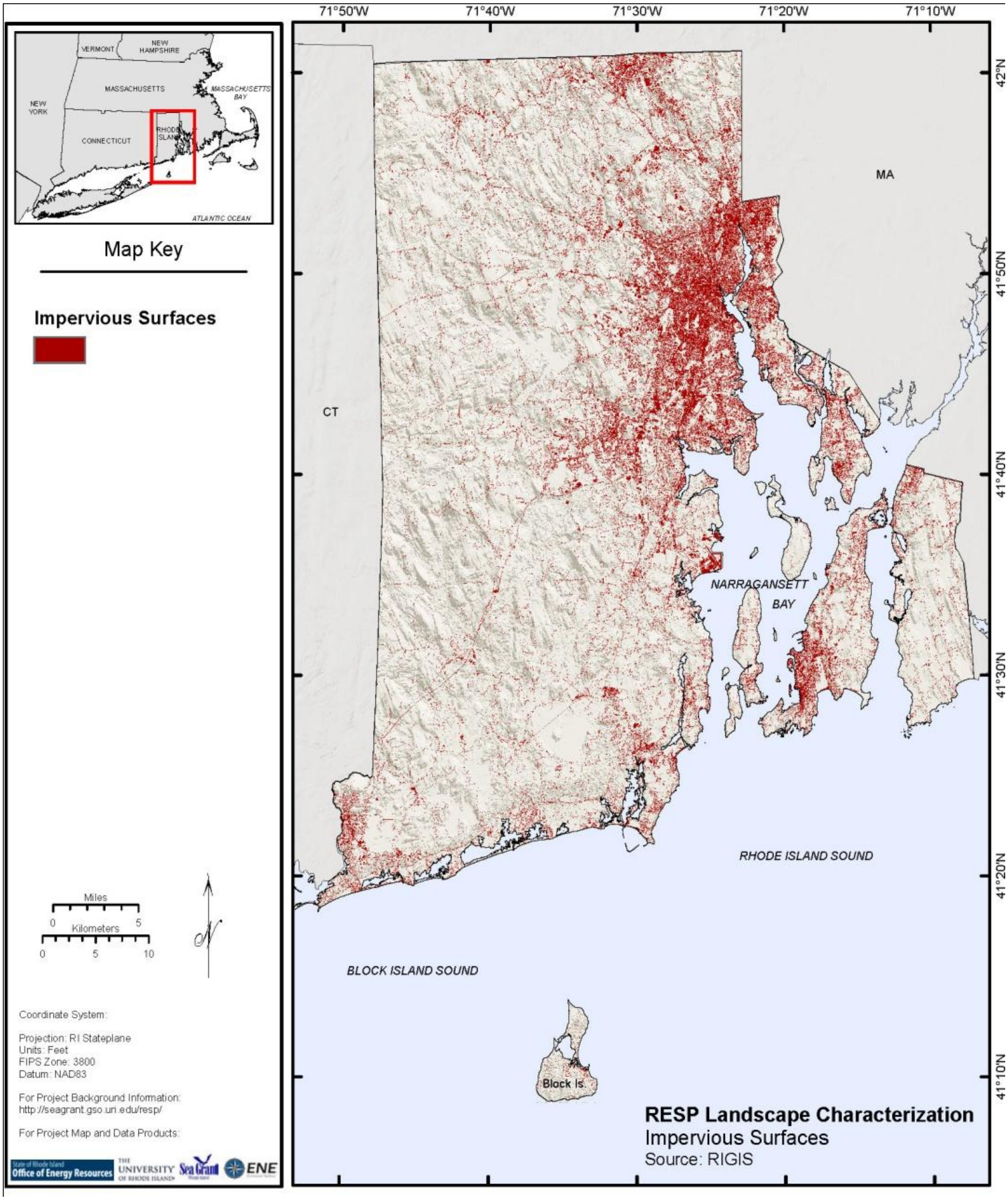
Ch. 1 Figure 32. Rhode Island Population Density (Represented as Standard Deviations Above/Below the Mean Value).



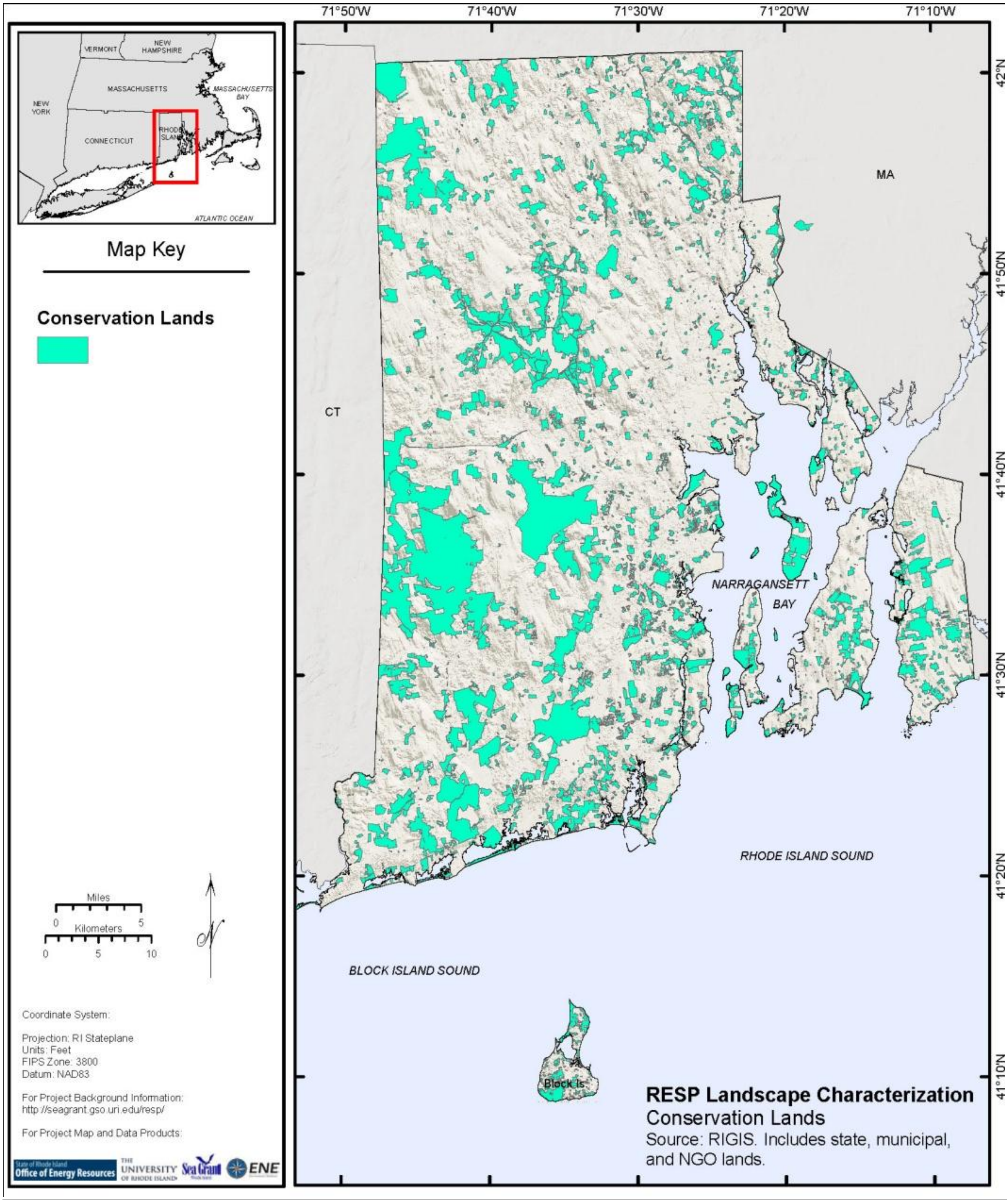
Ch. 1 Figure 33. Wetlands with a 50 foot (15 meter) Buffer.



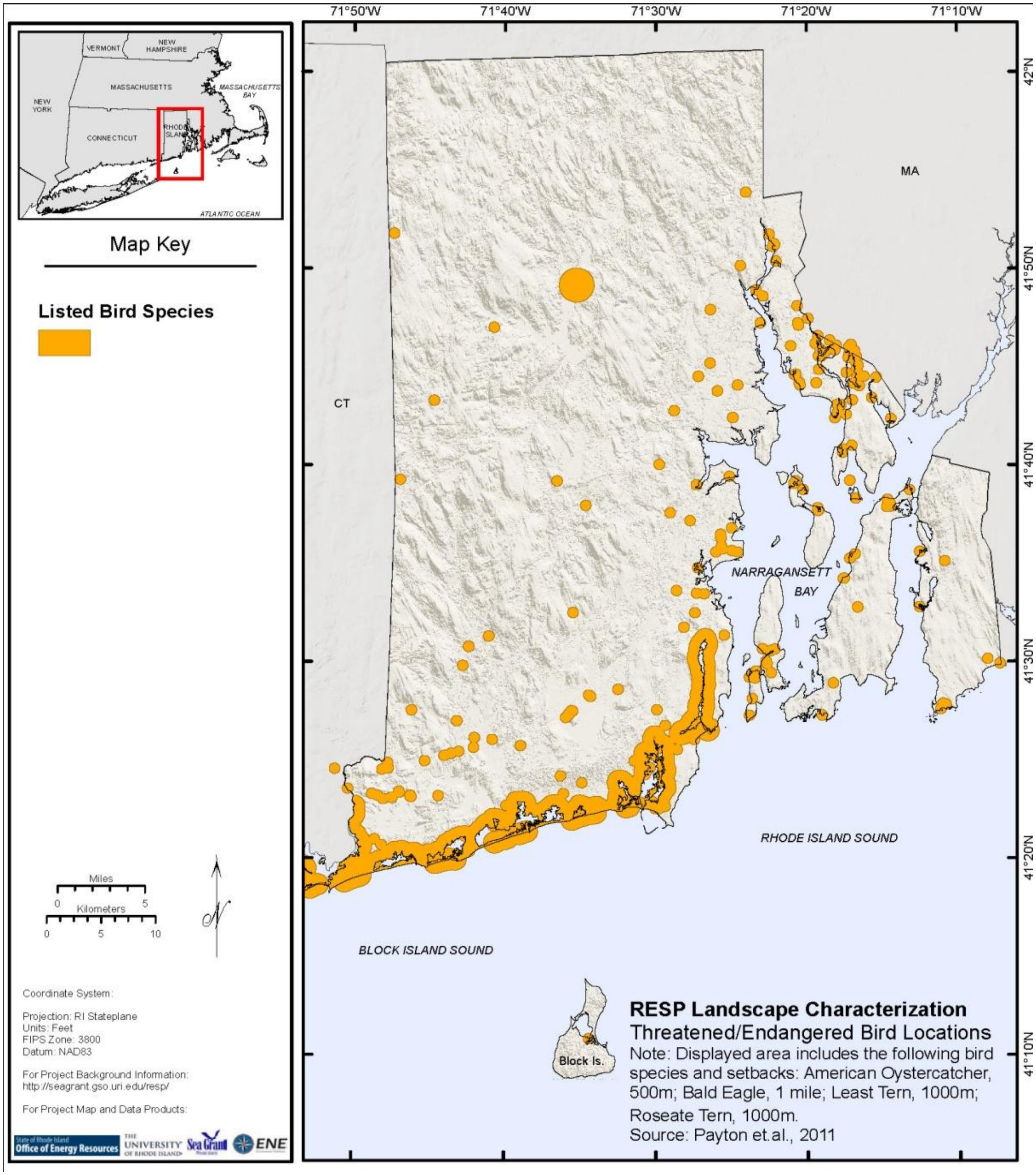
Ch. 1 Figure 34. Rhode Island Lakes, Streams and Rivers with a 100 foot (30 meter) Buffer.



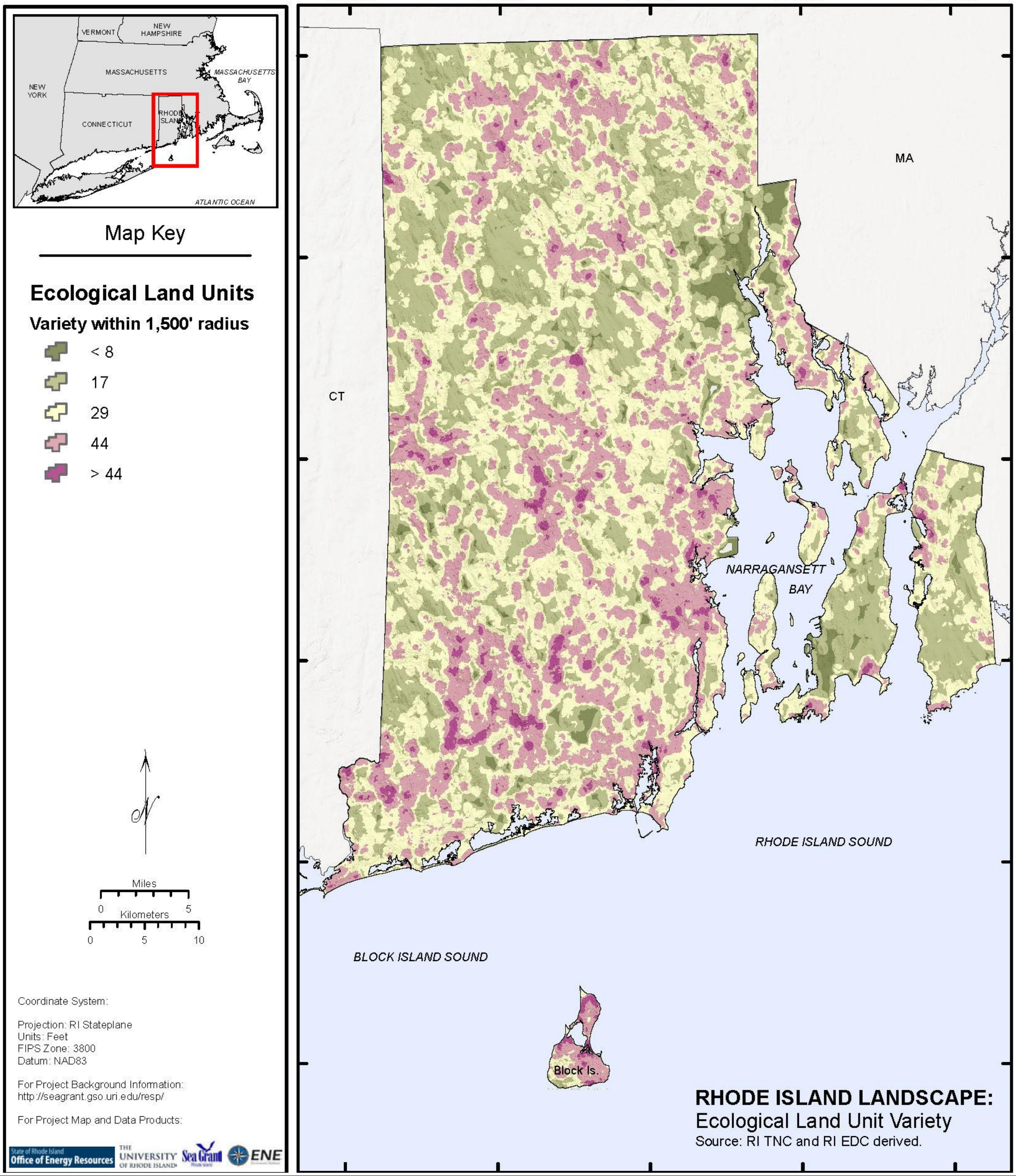
Ch. 1 Figure 35. Impervious Surfaces in Rhode Island (Used as a Proxy for Roads and Parking Lots).



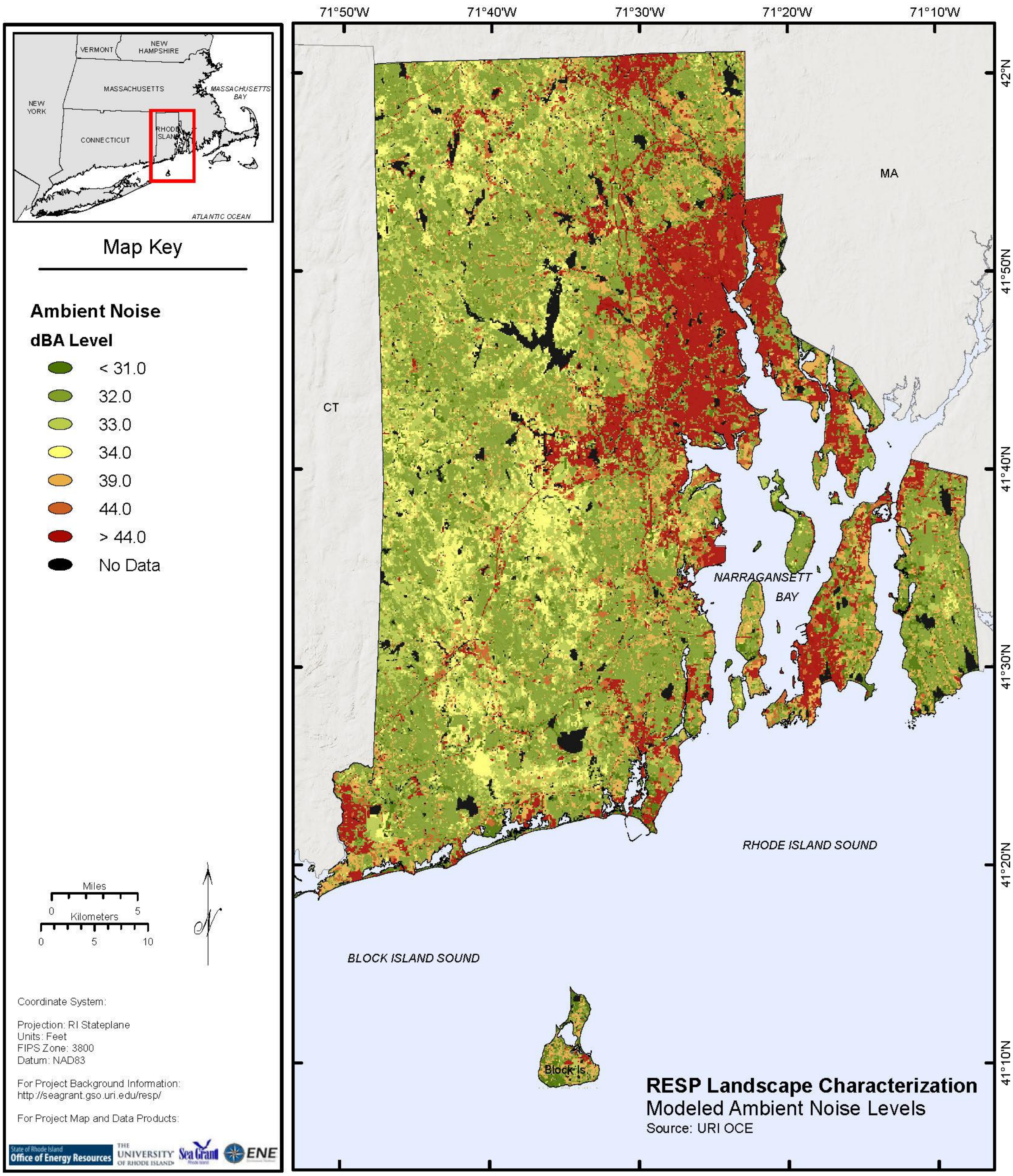
Ch. 1 Figure 36. Conservation Lands Protected by State, Municipal and Non-Profit Organizations.



Ch. 1 Figure 37. Habitat Areas for Threatened and Endangered Birds with Appropriate Buffers as prescribed in Paton et al. (2012).

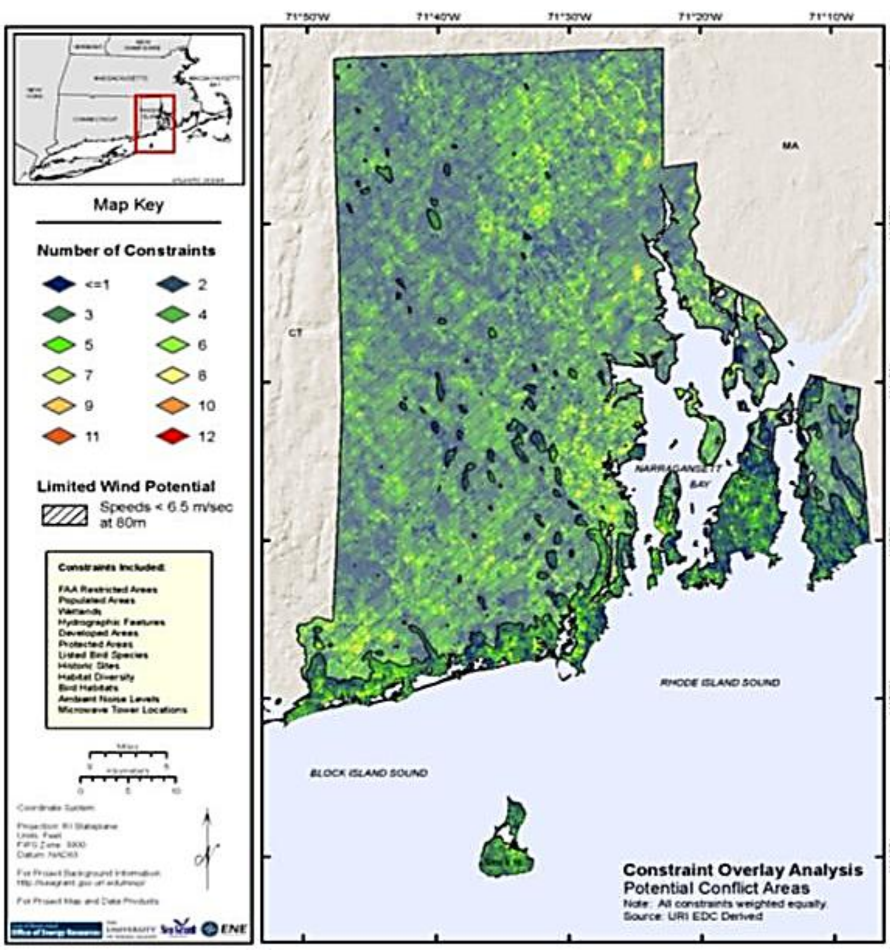


Ch. 1 Figure 38. A measure of biodiversity using Ecological Land Units.



Ch. 1 Figure 39. Modeled background noise level calculated based on land use (Potty and Miller 2012).

The precise combination of factors to take into consideration when siting a wind turbine is determined by the relevant federal, state and local regulations and in conjunction with affected community members. Municipalities may choose to use to include as many or as few map layers as they would like when using the RESP siting tool. As shown in Ch. 1 Figure 40, no part of the state would be completely free from anticipated impacts if a wind turbine were to be installed there. Ch. 1 Figure 40 rates different parts of the state taking into account all of the siting considerations listed in Ch. 1 Table 16. While one or more of these considerations is applicable in almost every part of the state, this does not necessarily mean that there are no developable sites. Rather, it means that municipalities will have to carefully weigh a range of priorities when considering which potential impacts matter to their communities the most. This type of information when combined with the wind resource maps presented in Section 2 of this chapter can help in identifying the most suitable sites for development. In addition, municipalities can use this information when reviewing proposed projects to ensure a developer has considered all the necessary factors in their permit application.



Ch. 1 Figure 40. Results of Initial Constraint Analysis

4.2 Siting Tools

SECTION SUMMARY

- The RESP research team developed a computerized siting tool to aid community members, municipalities, and developers in identifying the effects of placing wind turbines in different locations. This tool is available to the public at RI Energy.org.
- The RESP siting tool enables viewers to analyze the distribution of factors presenting both "hard" and "soft" constraints in Rhode Island. Hard constraints represent factors that make it impossible to site wind turbines in a particular location. Soft constraints represent factors that may require careful evaluation when siting turbines nearby.
- The RESP siting tools enables the viewer to visualize the distribution of FAA restrictions, population density, wetlands, water bodies, impervious surfaces, conservation lands, areas with listed bird or bat species, bird habitats, communication towers, historical sites, Ecological Land Units (i.e., a habitat diversity index), and background noise.
- The RESP siting tool allows viewers to assess the amount of power that could be produced at a given location, to impose hypothetical setbacks around features of concern, and to model the acoustic and shadow flicker impacts of a hypothetical turbine at a given site.

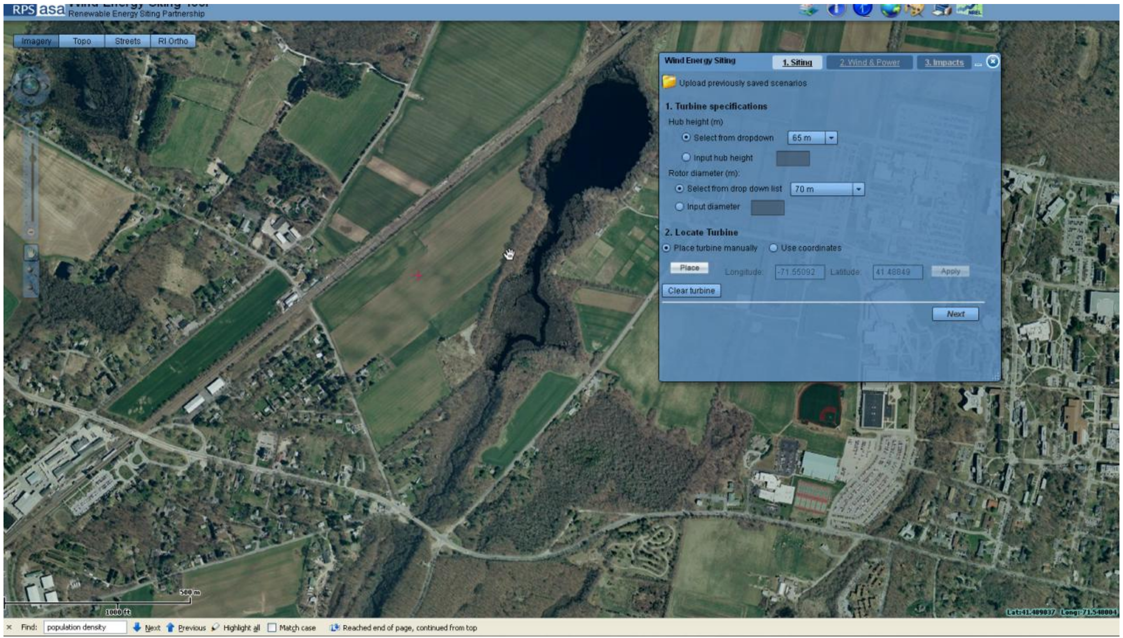
Drawing on the map layers presented above, the RESP developed several web-based tools to allow users to visualize how a proposed project site and surrounding areas may be impacted by structural failure, noise, and shadow flicker.

These wind siting tools will be available on RI Energy.org, along with all the map layers discussed in Section 2. This section presents an overview of the capabilities and functions of the tool. The description that follows adheres to the same structure employed in the siting tool website. The tool can be viewed via three tabs: (1) siting; (2) wind and power; and (3) impacts (see Ch. 1 Figure 41). The functionality of each of these tabs is described below.

Ch. 1 Figure 41. Wind Energy Siting Tool Tabs Format.

Siting

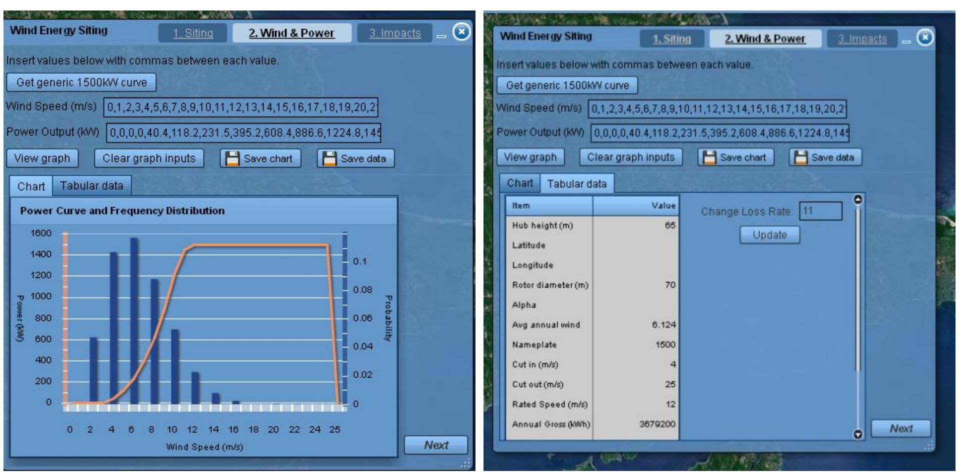
Users can input the specific location of a hypothetical turbine using latitude and longitude coordinates, or by selecting a site on the map. Once a user has chosen a site, the tool prompts the user to select the size of the hypothetical turbine (see Ch. 1 Figure 42). This information is necessary for performing the analysis provided in the other two tabs (Wind & Power and Impacts). The siting tool marks the spot of the hypothetical turbine with a red cross.



Ch. 1 Figure 42**. Siting Tab of the Wind Siting Tool.**

Wind & Power

The purpose of the Wind & Power tab is to allow users to assess the amount of power that could be produced at a given location. Based on the specifications of the turbine provided by the user, the tool creates a power curve showing the frequencies of different wind speeds at the site (Ch. 1 Figure **42**).



Ch. 1 Figure 43. Wind Siting Tool- Turbine Specification and Power Analysis Capabilities.

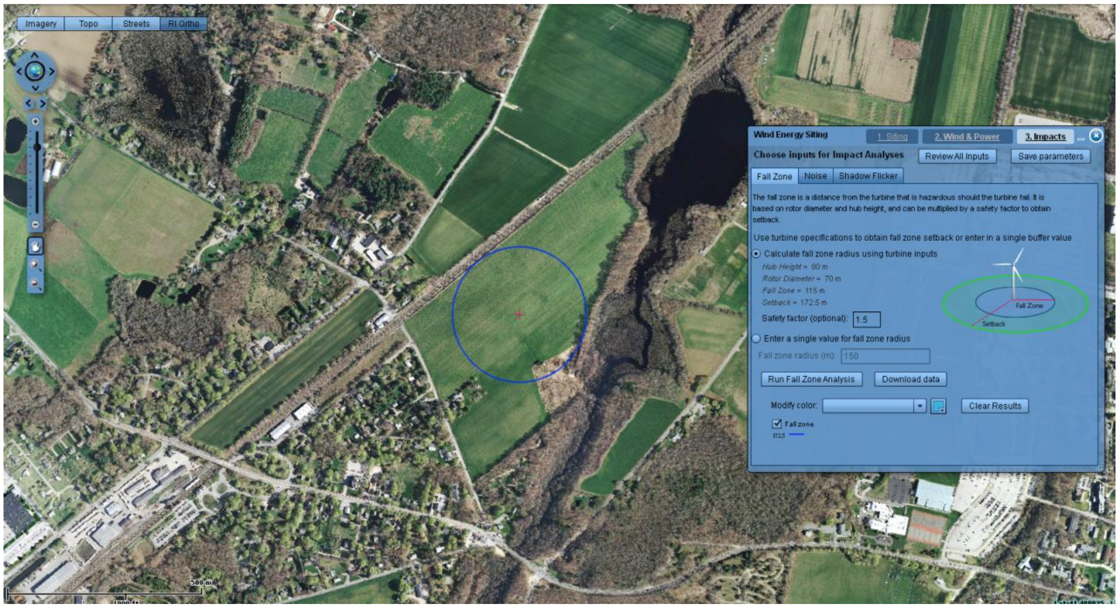
Impact

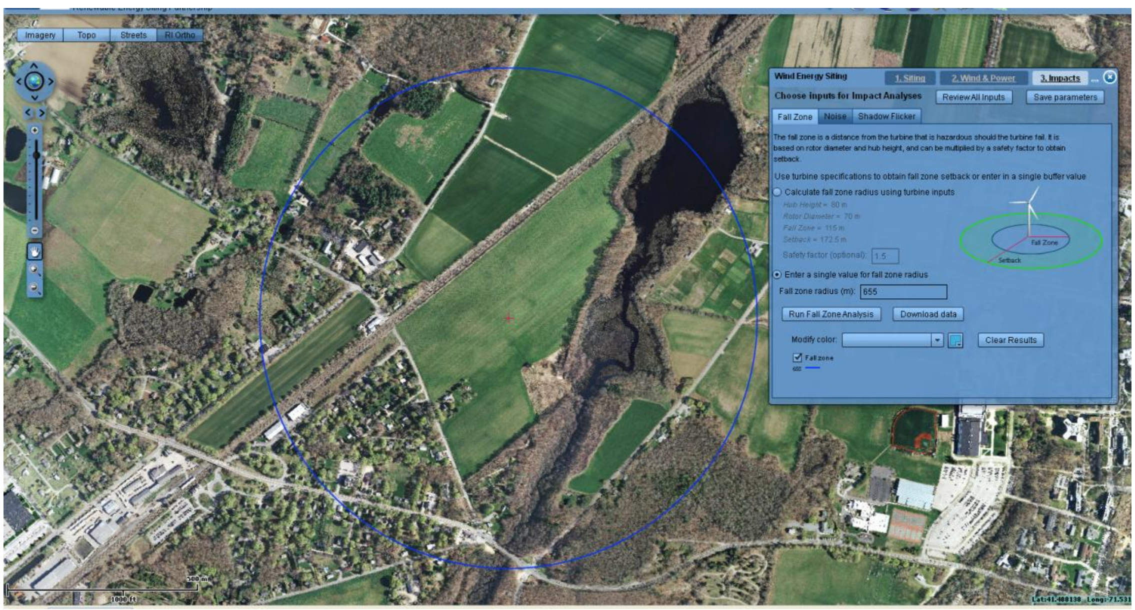
The Impact Tab allows users to view examples of safety setbacks and to observe the predicted zones around a turbine that are likely to experience certain levels of noise or shadow flicker.

With the Fall Zone Tool, a user can choose to view a setback based on the size of the turbine, as specified in the turbine specifications selected by the user, or to allow the tool to predict a fall zone radius using the formula proposed by Rogers et al. (2011), described in Section 3.1 (See Ch. 1 Figure 44).

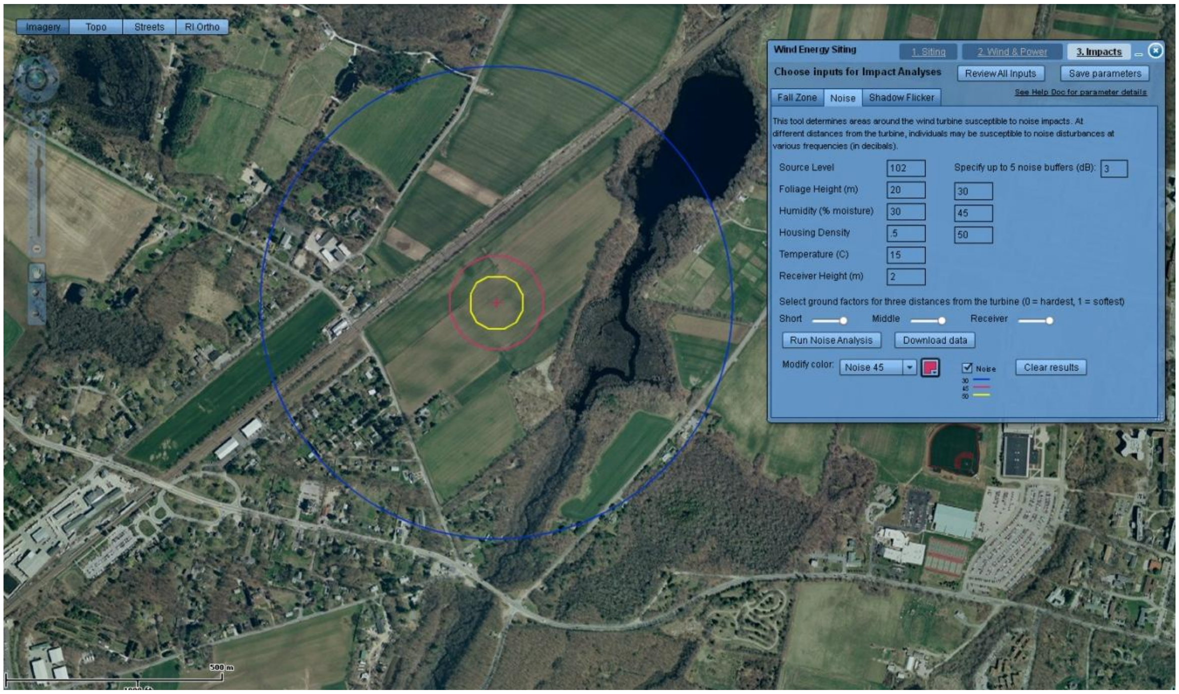
The Noise Modeling Tool allows users to input the source volume level of the turbine selected, as well as parameters of the locale, such as foliage height, humidity, housing density, temperature, and the receiver height (e.g. the height of a person hearing the noise emitted). Up to three noise thresholds can be mapped at once (see Ch. 1 Figure 45), allowing the user to visualize the impact of turbine noise at several different distances from the turbine.

Lastly, with Shadow Flicker Tool, users can model up to five shadow flicker zones, each representing a predicted maximum number of hours of shadow flicker per year (see Ch. 1 Figure 46 and Potty et al. 2012). Like the other two tools, this tool enables community members to visualize how they and their neighbors might be affected by a proposed turbine, and to explore the predicted impacts associated with an array of alternative siting options.

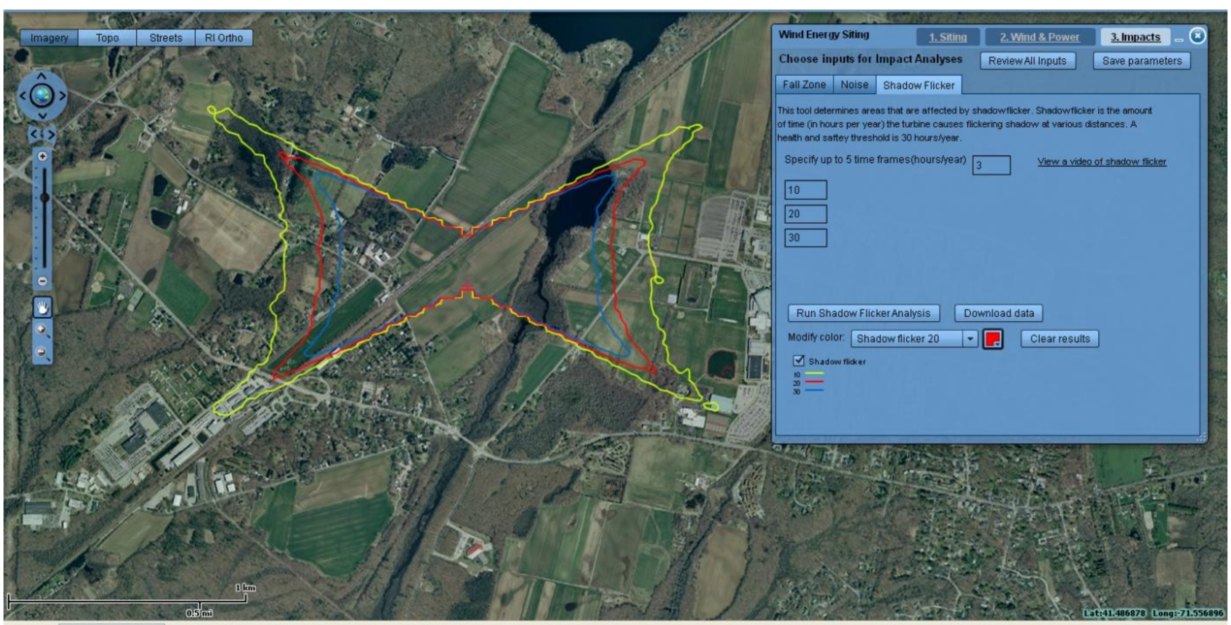
a) 

b) 

Ch. 1 Figure 44. Fall Zone Setbacks (a) based on the height of the turbine specified (e.g. 1.5* Total Turbine Height); (b) Setback based on a certain radius (e.g. distance caluclated by mehtodology described in Section 0 by Rogers et al. (2011)).



Ch. 1 Figure 45. Noise Impact Zones.



Ch. 1 Figure 46. Shadow Flicker Impact Zones.

Please note: A step-by-step case example of the inputs and results produced from this siting tool is provided at the end of Chapter 4 of this document and online at RI Energy.org.

5. Overview of Relevant Wind Energy Regulations and Policy

Section Summary

- The federal Endangered Species Act (ESA) may come into play if a wind turbine affects or is expected to affect any species listed as endangered or threatened by the U.S. Fish and Wildlife Service. Two listed bird species and one listed bat species are known to occur in Rhode Island.
- The federal Migratory Bird Treaty Act (MBTA) may be relevant if a wind turbine affects any migratory bird species protected under the Act. Over 1000 species are protected nationwide under the MBTA.
- The federal Bald and Golden Eagle Protection Act (BGEPA) may be relevant if a wind turbine affects a Bald Eagle. There is currently one known nesting pair of Bald Eagles on the Scituate Reservoir.
- Federal Aviation Administration (FAA) restrictions on use of airspace apply to all structures over 200ft (61m) tall. FAA imposes setbacks on tall structures near airports that vary according to the size of the airport runway.
- The National Historic Preservation Act (NHPA) is intended to preserve the historical and cultural foundations of the nation. It provides for a National Register of Historic Places, a State Historic Preservation Officer, and a Tribal Historic Preservation Officer. Rhode Island's SHPO and the Narragansett Indian Tribe's NITHPO should be consulted when siting wind energy projects.
- The federal government offers tax credits, loan guarantees, and bonds to support new development of renewable energy. These incentives are subject to frequent change.
- The Rhode Island Department of Environmental Management's Rhode Island Natural Heritage Program (RINHP) oversees a state Endangered Species List. RINHP currently lists eight species as state-endangered.
- Under Rhode Island Nuisance Law, any citizen may bring action against another citizen causing or permitting an alleged nuisance either directly or indirectly. Noise may qualify as a nuisance. In other states, nuisance suits have successfully been brought against wind turbine owners by neighboring residents.
- In recent years, Rhode Island has enacted several policies to facilitate renewable energy in the state, including the Renewable Energy Standard, which states that 16% of the electricity used in the state must derive from renewable sources by 2019, as well as interconnection incentives and tax benefits.

Existing policies and regulations at both the state and federal levels represent an important source of guidance on wind energy siting. Most siting-relevant regulations are specific to a single impact, such as birds and wildlife, air traffic, or historical impacts. While most of these regulations do not specifically address wind energy as a regulated activity, they nonetheless have a bearing on the development of wind turbines, since turbines represent a development activity with potential consequences of concern for the entities or activities that these regulations are designed to protect.

In addition, several state and federal policies aim to foster renewable energy projects such as wind turbines through monetary or other incentives. Recognizing that the relative novelty of most forms of renewable energy can at times act as an impediment to economic success, such incentives aim to offset the economic burden associated with installing new and unfamiliar energy technologies.

5.1 Federal policies and Regulations

Several federal policies and regulations may be relevant when considering wind energy development in Rhode Island. The primary federal constraints on wind energy come in the form of laws that protect birds and bats and regulations that protect airspace used by planes. Ch. 1 Table 17 offers a more exhaustive list of federal policies and regulations that might be relevant when siting wind turbines. *Endangered Species Act* (16 U.S.C. § et seq.): The Endangered Species Act (ESA) of 1973 makes it unlawful for any person in the United States to "take" an endangered species. To "take" is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct (16 U.S.C. § 1532)." The ESA is enforced by the U.S. Fish and Wildlife Service (USFWS). Anyone who knowingly takes an endangered species as defined in this section is subject to civil fines up to $25,000 per violation and criminal fines of up to $50,000 plus one year imprisonment. However, a person may avoid these penalties by applying to the FWS for an Incidental Take Permit (ITP).

An ITP makes its holder exempt from penalties for taking an endangered species provided that "such a taking is incidental to, and not the purpose of the carrying out of an otherwise lawful activity (16 U.S.C. § 1539)." A person may seek an ITP from the USFWS by submitting a Habitat Conservation Plan (HCP). The HCP must include a description of potential impacts resulting from the taking, proposed steps to minimize and mitigate such impacts, and alternatives to the taking.

The legal implications associated with wind turbine impacts on avian and bat populations rose to prominence in the citizen-suit action *Animal Welfare Institute et al. v. Beech Ridge Energy LLC, et al.* In 2009, a group of West Virginia citizens sued Beech Ridge Energy on the grounds that a wind farm under construction at the time posed a significant threat to Indiana bats, a species protected under the ESA. The court found in favor of the plaintiffs, stating that the developer had not performed adequate pre-construction surveys of the site. In addition, the court affirmed that groups of citizens have grounds to seek remedies for violations of the ESA, that they may do so before any actual harm to a species has occurred, and that reasonable certainty that harm is likely to take place is a sufficient standard to demonstrate a "taking" under the ESA.

At the time of this writing, there are two federally listed bird species known to utilize habitat in Rhode Island: the Roseate Tern and the Piping Plover. More information on these species, their habitat, and their potential vulnerability to the impacts of wind turbines is presented in Section 3.6 of this chapter and in Paton *et al.* (2012), included in Volume II of the RESP report.

Migratory Bird Treaty Act (16 U.S.C. § 703-712): The Migratory Bird Treaty Act (MBTA) of 1918 prohibits the taking, killing, possession, transportation, import, and export of migratory birds, their eggs, parts, and nests. Penalties apply regardless of whether a violation is intentional or not. Over one thousand species of birds are protected under the MBTA, including eagles and other raptors, waterfowl, shorebirds, seabirds, wading birds, and passerines. Fines for misdemeanor convictions under the Migratory Bird Treaty Act can be as high as $15,000 per violation.

Bald and Golden Eagle Protection Act (16 U.S.C. § 668): The Bald and Golden Eagle Protection Act (BGEPA) prohibits the taking of any bald or golden eagle, alive or dead, or any part, nest, or egg thereof. Under the BGEPA, "take" is defined as to "pursue, shoot, shoot at, poison, wound, kill capture, trap, collect, molest, or disturb (16 U.S.C. § 668C)" an eagle. Both criminal and civil penalties may be sought for the violation of the BGEPA. As with the ESA, the BGEPA contains provisions allowing a person to avoid penalties by obtaining an ITP for the limited, non-purposeful take of eagles by persons engaging in otherwise legal actions such as the operation of utilities (50 C.F.R. 22.2 & 22.27).

At the time of this writing, there is one nesting pair of Bald Eagles in Rhode Island, living at the Scituate Reservoir (Paton *et al.* 2012). Based on interpretation of the Bald and Golden Eagle Act, the USFWS suggests avoiding the placement of wind turbines within one mile of a Bald Eagle nest. Thus, plans for any turbine near the Scituate Reservoir should take into consideration this nest site, and any plans to install a wind facility near the Connecticut or Massachusetts border near large water bodies should contact state wildlife agencies to insure there are no nest Bald Eagles nearby (Paton *et al.* 2012).

Federal Aviation Administration (FAA) Restrictions (14 C.F.R § 77)*:* Federal legislation governing the "safe, efficient use and preservation of the navigable airspace" requires developers to receive FAA clearance prior to erecting any structure measuring over 200 feet (61 meters) tall as well as any structure near an airport. Size restrictions on structures near airports depend on the size of the airport. FAA restrictions would require a 3.8-mile (6.1 km) setback from T.F. Green Airport, but setback distances required for smaller airports may be shorter. In addition, wind turbines must comply with FAA lighting requirements.

In considering a proposal, the FAA solicits comments from other federal agencies with radar assets, such as the Department of Defense, the Department of Homeland Security, and the National Oceanic and Atmospheric Administration. If any of these agencies objects to the construction of the turbine, the FAA issues a Determination of a Presumed Hazard, which can be appealed or renegotiated by the developer.

National Historic Preservation Act (16 U.S.C § 470): The National Historic Preservation Act (NHPA) was enacted in 1966 to assure that "the historical and cultural foundations of the Nation should be preserved as a living part of our community life and development in order to give a sense of orientation to the American people (16 U.S.C. 479b(2))." The NHPA's central accomplishment is the establishment of a National Register of Historic Places that lists "districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, engineering, and culture (16 U.S.C. 470a(a))."

In addition, NHPA provides for the establishment of a State Historic Preservation Officer (SHPO) in each state. The role of a SHPO is to implement a State Historic Preservation Program, nominate eligible properties to the National Register, administer federal assistance for historic preservation within the state, and cooperate with federal agencies, local governments, organizations, and individuals to ensure that historic properties are taken into consideration at all levels of planning and development. At the time of this writing, Rhode Island's SHPO is Edward Sanderson at the Rhode Island Historic Preservation & Heritage Commission (http://www.rihphc.state.ri.us/). The 1992 Amendments to the NHPA enabled tribal representatives to take on the role of a SHPO for their respective tribes by designating a Tribal Historic Preservation Officer (THPO; Section 101(d)(2)). At the time of this writing, the THPO for the Narragansett Indian Tribal Historic Preservation Office (NITHPO) is John Brown (NATHPO 2012).

Section 106 of the NHPA requires federal agencies to evaluate the impacts to listed historic places of any projects ("undertakings") that are conducted, funded, and/or approved by a federal entity. Section 106 also requires federal agencies to consult with the Advisory Council on Historic Preservation, a 23-member council made up of members of the public and private sectors, also established by the NHPA. The Advisory Council's implementing regulations, "Protection of Historic Properties" (36 CFR Part 800), lay out the complete Section 106 process. Wind energy projects must abide by this process only when supported by federal funding.

To begin the Section 106 process, the lead federal agency responsible for the undertaking must first identify all parties to a consultation – relevant SHPO and THPO, local governments, the public, and additional parties with a special interest in the undertaking in question. Next, the lead agency identifies the Area of Potential Effect (APE) affected by the proposed undertaking, and gathers information from consulting parties, other experts, and written sources to identify historic properties in the APE. If the lead agency finds that there are historic sites in the APE, it assesses the anticipated effects of the proposed undertaking on these properties to determine whether any of these effects are adverse. An adverse effect is one that "may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association (36 CFR Part 800.5)." If the lead agency issues a finding of no adverse effect, it must give consulting parties 30 days to review the finding and contest it if they choose. If the lead agency finds that an undertaking may cause adverse effects to historical properties, it must engage consulting parties to develop alternatives or modifications to the undertaking that could avoid, minimize, or mitigate these effects. Following the consultation, the lead agency commits to a memorandum of agreement with SHPO/THPO.

Ch. 1 Table 17. Federal Regulations that May be Applicable to Wind Energy Development (Source: AWEA 2008). (Relevance of these regulations may vary on a case by case basis).

Regulatory Authority	Statute	Permit/Approval	Description	Triggers
Federal				
Lead Agency varies by project Council on Environmental Quality Regulations (CFR 1500-1508) and supplemental regulations from lead agency	National Environmental Policy Act (42 USC 4321)	Record of Decision or FONSI or Categorical Exclusion	Establishes national mandate for federal agencies to review environmental impacts of proposed actions Process can be combined with state and local environmental reviews	▪ Federal permit or approval required ▪ Siting on federal lands ▪ Accessing federally owned transmission line ▪ Receipt of federal grants
U.S. Fish and Wildlife Service (50 CFR 13 and 17)	Endangered Species Act (16 USC 1531-1544)	Endangered Species Act Consultation and Incidental Take Permit	Regulates activities affecting threatened and endangered species: Section 3 (16 USC 1532) defines terminology Section 7 (16 USC 1536) establishes federal interagency consultation Section 9 (16 USC 1538) establishes prohibited actions Section 10 (16 USC 1539) establishes permits and exceptions Section 11 (16 USC 1540) describes penalties and enforcement	▪ Consultation with FWS under Section 7 always recommended ▪ Activities that may result in take or harm to species and their habitat, such as site clearing and wind turbine operation
U.S. Fish and Wildlife Service (50 CFR 13and 21)	Migratory Bird Treaty Act (16 USC 703-712)	Consultation	Prohibits harm, possession, or take of migratory bird species, nests, and eggs. Strict liability statue.	▪ Potential impact to migratory bird species protected by the act
U.S. Fish and Wildlife Service (50 CFR 13 and 22)	Bald and Golden Eagle Protection Act (16 USC 668-668d)	Consultation Golden Eagle Nest Take permit	Prohibits harm, possession, or take of bald and golden eagles. Strict liability statue.	▪ Potential impact to bald or golden eagle ▪ Necessity for moving golden eagle nest

Regulatory Authority	Statute	Permit/Approval	Description	Triggers
Federal (Cont'd)				
Advisory Council on Historic Preservation, Tribal Historic Preservation Office and State Historic Preservation Office (36 CFR 60 and 800)	National Historic Preservation Act (16 USC 470)	Section 106 Consultation	Requires federal agencies to review impacts to historic and Tribal resources and allows ACHP to provide comments. Consultation authority delegated to SHPO and THPO.	▪ Consultation with the SHPO is always recommended to determine need for Section 106 Consultation ▪ Federal permit or approval required ▪ Activity may impact property listed in or eligible for listing in the National Register of Historic Places (NRHP) ▪ Activity may impact Tribal resources
U.S. Army Corps of Engineers (33 CFR 320-331 and 40 CFR 230)	Clean Water Act (33 USC 1251 et seq) Section 404 (33 USC 1344)	Individual, general, and nationwide permits	Regulates discharge of dredged or fill materials into waters of the United States	▪ Activities that may impact federal waters, including wetlands
U.S. Army Corps of Engineers (33 CFR 320-331)	Rivers and Harbors Act of 1899 (33 USC 401 et seq) Section 10 (33 USC 403)	Section 10 Permit	Regulates obstructions to navigable waters of the United States	▪ Building or replacing bridges
Environmental Protection Agency and state agencies (40 CFR 122 and 123)	Clean Water Act (33 USC 1251 et seq) Section 402 (33 USC 1342)	National Pollution Discharge Elimination System (NPDES) Stormwater Permit	Regulates discharges into waters of the United States. Usually delegated to state authority.	▪ Potential for discharge from site assessment, construction, and operation
Federal Aviation Administration (14 CFR 77)	49 USC 44718	Notice of Proposed Construction (Form 7461-1) Hazard Determination	Notifies FAA of proposed structures that might affect navigable airspace. Form requires proposed markings and lighting. FAA must review possible impacts to air safety and navigation, as well as the potential for adverse effects on radar systems.	▪ Construction or alteration of structures standing higher than 200 feet above ground level ▪ Construction or alteration of structures near airports ▪ 14 CFR 77.13 provides details ▪ Siting within radar line-of-sight of an air defense facility
Environmental Protection Agency (40 CFR 112)	Oil Pollution Act (33 USC 2701 et seq)	Spill Prevention, Control, and Countermeasure (SPCC) Plan	Establishes procedures, methods, and equipment requirements to prevent and contain oil spills	▪ May apply to fuel stored on site for emergency power generator or other purpose. ▪ SPCC rules currently being amended
Environmental Protection Agency	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) (42 USC 9601-9675)	ASTM Environmental Site Assessment	CERCLA is the principal statue that governs liability with respect to contaminated properties	▪ Contaminated property

Federal incentives for wind energy development (100 kW – 1.5MW)

Over the years, a variety of federal incentives have been instituted to foster development of renewable energy. These are sometimes of short duration and are always subject to change, due to Congressional reauthorization processes. At the time of the RESP process, the following federal incentives are applicable wind as well as other forms of renewable energy.*Renewable Energy Production Tax Credit* (42 U.S.C. § 134): Enacted by the Energy Policy Act of 1992, the Federal Production Tax Credit applies to many forms of renewable energy, including wind and solar. Upgrades to existing hydropower facilities are also eligible. To qualify for the tax credit, projects must be owned by a non-profit, state, municipality, tribe, or electrical utility. Tax credit may only be received during the first ten years of operation. The rate of the tax credit varies with inflation. Wind power projects are currently eligible to receive 2.2¢/kilowatt-hour, and hydropower projects are eligible to receive 1.1¢/kilowatt-hour. The Tax Production Credit has been renewed several times. The wind credit now expires on December 31, 2012, while credits for other forms of renewable energy extend until December 31, 2013.

Business Energy Investment Tax Credit (ITC) (26 U.S.C § 45)*:* The ITC is a Corporate Tax Credit for energy systems placed in service on or before December 31, 2012. For small wind turbine systems placed in service after December 2008 and solar energy properties (excluding passive solar systems and solar pool-heating systems), the tax credit is equal to 30% of expenditures with no maximum credit. For wind projects greater than 100kW: The American Recovery and Reinvestment Act (ARRA) of 2009 not only extended the Business Energy Tax Credit for smaller wind systems and solar projects by eight years, but also made the 30% ITC available to entities that qualified for the Renewable Energy Production Tax Credit (PTC). However, for wind energy projects of more than 100kW this credit is only available through the PTC in-service deadline of December 31, 2012.

New Markets Tax Credit: This program was authorized by the Community Renewal Tax Relief Act (26 U.S.C. § 45D) of 2000. Administered jointly by the Community Development Financial Institution Fund and the Internal Revenue Service, it provides federal income tax credits to investors in Community Development Entities (defined as organizations with a primary mission of serving or providing investment capital for low-income communities or persons). Though New Market Tax Credits are not directly intended as an incentive to renewable energy projects, they have at times been used successfully to fund wind energy sites in low-income areas. For instance, in 2011, Rockland Trust Community Development made a $2.25 million loan to a company in Fall River, MA, to develop a wind turbine research facility (Rockland Trust Community Development 2012).

Public Utilities Regulatory Policy Act (16 U.S.C § 46): The Public Utilities Regulatory Policy Act (PURPA) of 1978 is primarily concerned with the regulation of utilities providers, but it also offers one provision which has applicability as an incentive to purchase renewable energy resources. Specifically, in cases where a utility is able to purchase electricity from a small renewable energy producer that costs less than it would to generate power itself (through any power generation means, including fossil fuels), PURPA requires the utility to purchase electricity from the renewable energy source instead of producing it through conventional means. At present, the low cost of conventional fuels compared to renewable energy makes this scenario unusual, but in the event of a steep increase in the price of non-renewable energy or decrease in the price of wind power technologies, this provision of PURPA may effectively compel utilities to purchase electricity generated by wind power facilities.

Clean Renewable Energy Bonds (26 USC § 54C): Clean Renewable Energy Bonds (CREBs) are available to certain public power providers, governmental bodies, and cooperative electric companies. These entities may issue bond for the finance of capital expenditures required for new renewable energy projects. At the time of this writing, the Treasury has allocated all available bonds under the most recent award, and it is unclear whether more CREBs will be issued; however, bond issuers may still have funding available to issue bonds for additional renewable energy projects. CREBS are applicable to all forms of energy that generate electricity from "clean" sources, including renewable energy.

Department of Energy Loan Guarantee Program (42 U.S.C. 16511– 16514): This program was instituted in Title XVII of the Energy Policy Act of 2005, and was updated by the ARRA of 2009. Section 1703 authorizes the Secretary of Energy to make loan guarantees for projects that ''avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued.'' Projects supported under this program are typically unable to obtain conventional private financing due to high technology risks. Eligible projects may include wind, solar, or hydropower projects, but must employ a technology that is new or significantly improved and has not yet been deployed on a commercial scale.

U.S. Department of Agriculture (USDA) - Rural Energy for America Program (REAP): The USDA's Rural Energy for America Program supports renewable energy projects in rural areas through financial assistance to agricultural producers, small businesses, and entities that conduct energy audits in rural areas. Additionally, the REAP provides grants for eligible applicants to conduct renewable energy feasibility studies in order to qualify for REAP grants and guaranteed loans. The REAP includes: the Renewable Energy System and Energy Efficiency Improvement Guaranteed Loan and Grant Program; the Energy Audit and Renewable Energy Development Assistance Grant Program; and the Feasibility Studies Grant Program. Eligibility for REAP grants and guaranteed loans is limited to agricultural producers and small businesses. They are defined by the USDA as follows:

> "An agricultural producer is an individual or entity directly engaged in the production of agricultural products (crops, livestock, forestry products, hydroponics, nursery, and aquaculture) whereby 50 percent + or greater of their gross income is derived from the operations. A private entity is considered a small business in accordance with Small Business Administration's Small Business Size Standards." (http://www.rurdev.usda.gov/BCP_ReapResEei_Eligibility.html)

More information is available at http://www.rurdev.usda.gov/BCP_Reap.html.

USDA – High Energy Cost Grant Program: The High Energy Cost Grant Program is a federal program that awards competitive grants ranging from $20,000 to $3 million to help fund projects designed to lower energy costs in rural areas. Established in 2000, the program targets rural communities with energy costs that are in excess of the national average by at least 275%. Both renewable energy and energy conservation/efficiency projects are eligible for High Energy Cost Grants, though the program is not limited to such projects. Due to the high energy cost requirement, Rhode Island eligibility for this program is limited to Block Island. More information is available at http://www.rurdev.usda.gov/UEP_Grant_Program.html.

5.2 State Policies and Regulations

Several state agencies may have a bearing on the process of siting wind turbines in the Rhode Island (see Ch. 1 Table 18). In addition, state policies and regulations that protect endangered species and maintain public quality of life may come into play in the development of wind energy. This section provides a brief summary of these policies and regulations. Further details on Rhode Island regulations pertinent to wind energy development are included in Biggs (2012), included in Volume II of the RESP report.

Ch. 1 Table 18. Rhode Island State Agencies and Boards with Jurisdiction over some Aspect of Wind Energy Development.

General charge	Relevance to wind energy development
The Office of Energy Resources, (OER) Established by RIGL 42-140, Website: www.energy.ri.gov	
General charge: ▪ Provides administration and oversight of energy policies, plans and programs to meet state and federal requirements; ▪ Offers programs to assist residents, businesses, cities and towns, and institutions with their energy needs; ▪ Works towards energy independence by increasing our supply options to include energy efficiency and renewable energy and to rely less on oil, gas, coal and nuclear energy that are produced outside our state.	Relevance to wind energy development: ▪ Drafts the state's energy plan in coordination with the Department of Administration, Division of Planning, Statewide Planning Program
Rhode Island Public Utilities Commission (RIPUC) Established by: RIGL 31-9, Website: www.ripuc.org	
General charge: ▪ Quasi-judicial body with regulatory capabilities over projects greater than 40MW ▪ Consists of members from the PUC, the State Division of Planning, and the Department of Environmental Management ▪ Was established to act as "the licensing and permitting authority for all licenses, permits, assents, or variances which, under any statute of the state or ordinance of any political subdivision of the state, would be required for siting, construction or alteration of a major energy facility in the state (RIGL 42-98)" ▪ Has the power to override local land use decisions, regarding any facility subject to its review.	Relevance to wind energy development: ▪ Renders the final licensing decision concerning the siting, construction, operation and/or alteration of major energy facilities ▪ Must "give priority to energy generation projects based on the degree to which such projects meet, criteria including, but not limited to: (i) Using renewable fuels, natural gas, or coal processed by "clean coal technology" as their primary fuel; (ii) Maximizing efficiency; (iii) Using low levels of high quality water; (iv) Using existing energy-generation facilities and sites; (v) Producing low levels of potentially harmful air emissions; (vi) Producing low levels of wastewater discharge; (vii) Producing low levels of waste into the solid waste stream; and (viii) Having dual fuel capacity."
The Coastal Resources Management Council (CRMC) Established by: RIGL 46-23, Website: www.crmc.ri.gov	
General charge: ▪ Has planning, regulatory and permitting powers for the marine waters of the state and the coastal zone, up to 200 ft. (61 m) inland. ▪ Is empowered to adopt special area management plans (SAMPS) "to provide for the integration and coordination of the protection of natural resources, the promotion of reasonable coastal-dependent economic growth, and the improved protection of life and property (§ 46-23-6 A(I))." These include the OCEAN SAMP, which was approved by the National Oceanic and Atmospheric Administration in July, 2011, and acts as a guiding document for off-shore wind development off Rhode Island's coast.	Relevance to wind energy development: ▪ Has explicit jurisdiction over power generating plants in the state greater than 40 MW, regardless of location. ▪ Any proposed project sited with the state's coastal zone, or may potentially impact the coastal zone may require a CRMC review and approval.
The Department of Environmental Management (DEM) Established by: (RIGL 42-17.1), Website: www.ridem.gov	
General charge: ▪ Has authority "to supervise and control the protection, development, planning, and utilization of the natural resources of the state, such resources, including but not limited to, water, plants, trees, soil, clay, sand, gravel, rocks and other minerals, air, mammals, birds, reptiles, amphibians, fish, shellfish, and other forms of aquatic, insect, and animal life." ▪ DEM's responsibilities with regard to energy include air quality protection ▪ Oversees forestry, solid waste and waste to energy facilities, and minerals.	Relevance to wind energy development: ▪ Has the lead role in Rhode Island's participation in Regional Greenhouse Gas Initiative (RGGI) ▪ Responsible for the review of water quality, wetland or wildlife impacts

Department of Administration, Division of Planning, Statewide Planning Program (SPP) Established by: RIGL 42-11-10, Website: www.planning.ri.gov	
General charge: ▪ Prepares, adopts, and amends plans "for the physical, economic, and social development of the state." ▪ Oversees the state guide plan, which is comprised of elements dealing with "land use; physical development and environmental concerns; economic development; housing production; energy supply, including the development of renewable energy resources in Rhode Island, and energy access, use, and conservation; human services." ▪ Serves as "a means for centralizing, integrating, and monitoring long-range goals, policies, plans, and implementation activities."	Relevance to wind energy development: ▪ Coordinates with OER on the State's Energy Plan ▪ Creating wind energy guidelines for the state in collaboration with the RESP
The Building Code Standards Committee Established by: RIGL 23-27.3-100.1.3, Website: www.ribcc.ri.gov/committee	
General charge: ▪ Adopts, promulgates, and administers a state building code for the purpose of regulating the design, construction, and use of buildings ▪ Has the authority to "adopt, maintain, amend, and repeal an optional energy conservation code, based on appropriate nationally and internationally recognized models, and to promulgate and administer the energy conservation code.	Relevance to wind energy development: ▪ May have oversight over the construction and engineering standards of wind turbines
Rhode Island Historical Preservation and Heritage Commission National Historic Preservation Act (36 CFR 800 Section 106) Rhode Island Historic Preservation Act (RIGL 42-45 et seq.), Website: http://www.preservation.ri.gov/	
General charge: • Project Review ensures that local, state, and federal projects avoid or minimize harm to significant historic properties by making historic preservation part of the formal planning process.	Relevance to wind energy development: • This review is required for federally funded or permitted projects by Section 106 of the National Historic Preservation Act (36 CFR 800). The Rhode Island Historic Preservation Act (RIGL 42:45 et seq.) requires a similar review for state and local projects. Projects which are entirely private undertakings are not subject to review unless a federal or state permit or license is required.

Rhode Island Endangered Species List: Section 20-37 of the Rhode Island General Laws prohibits persons in the state from buying, selling, offering for sale, storing, transporting, importing, exporting, or otherwise trafficking in any animal or plant or any part of any animal or plant whether living, dead, processed, manufactured, preserved, or raw, if the animal or plant has been declared to be an endangered species by either the United States secretaries of the interior or commerce or the director of the Rhode Island Department of Environmental Management. This prohibition is enforceable by DEM, state police, and city and town law enforcement authorities. Violators are subject to fines ranging from $500-$5,000 or imprisonment of up to one year, or both.

DEM's Rhode Island Natural Heritage Program (RINHP) maintains a list of all state endangered species. "State endangered species" are defined as native species in imminent danger of extirpation in Rhode Island, according to one or more of the following criteria: 1) formerly considered by the USFWS for federal listing as endangered or threatened, 2) only 1-2 known populations in Rhode Island, or 3) apparently globally rare or threatened, with 100 populations or less throughout their range.

At the time of this writing, the RINHP lists eight bird species as state-endangered: Cerulean Warbler (*Dendroica cerulean*), Yellow-breasted Chat (*Icteria virens*), Barn Owl (*Tyto alba*), Upland Sandpiper (*Bartramia longicauda*), Northern Harrier (*Circus cyaneus*), Peregrine Falcon (*Falco peregrinus*), American Bittern (*Botaurus lentiginosus*), and Pied-billed Grebe (*Podilymbus podiceps*). More information on these species, their habitat requirements, and vulnerability to wind turbines is included in Section 3.6 of this chapter, and in Paton et al. (2012), included in Volume II of the RESP report.

In addition, the RINHP designates three other categories of vulnerable species: "state threatened species" (defined as species deemed by the RINHP to be likely to become state-endangered if current trends in habitat loss or other detrimental factors remain unchanged), "state species of concern" (defined as species that are not deemed state-endangered or state-threatened at present, but suffer from rarity and/or vulnerability and may warrant endangered or threatened designation as more information becomes available) and "state historical species" (defined as species that have been observed in the state during the last 100 years, but which are currently unknown to occur).

These latter three designations are not enforceable under Section 20-37 of the Rhode Island General Laws in the same way that the state-endangered species designation is. Instead, the RINHP uses these lists to prioritize land protection activities, review development proposals, and provide information to other agencies on the potential impacts of development activities on rare species. At the time of this writing, the RINHP lists six species of bird as state-threatened, 33 species of bird a species of concern, and seven species of bird as state-historic. More information on these species, their habitat requirements, and vulnerability to wind turbines is included in Section 3.6 of this chapter, and in Paton et al. (2012), included in Volume II of the RESP report.

Nuisance Law (R.I Gen. Laws § 10-1-1): Under Rhode Island law, any citizen of the state or the Attorney General may bring action against another citizen causing or permitting an alleged nuisance either directly or indirectly. Action can be brought as a private nuisance (i.e., one that impairs the use and enjoyment of the complainant's land) or as a public nuisance (i.e., one that is injurious to public health or safety). Noise may qualify as a nuisance if it interferes with a person's use and enjoyment of his/her own property, but aesthetic displeasure is generally not considered a nuisance. To result in a legal determination of nuisance, a complainant must show that the harm he/she must bear as a result of the disturbance is greater than he/she can be expected to bear under the circumstances.

In Rhode Island, no nuisance complaints have taken place in connection with operation of a wind turbine. However, wind turbine nuisance cases have on occasion been successful in other states. In New Jersey, a 1982 case found in favor of a plaintiff who demonstrated that a 60-ft wind turbine located 10 feet from her home impaired her ability to sleep, read, and otherwise enjoy her property (Rose v. Chaiken, 453 A.2d 1378; N.J. 1982). The wind turbine in question was emitting noise that exceeded the allowable decibel level of the local noise ordinance. Few other residential claims against wind turbines have been successful at establishing a legal finding of nuisance.

State polices and incentives for wind energy development (100 kW – 1.5MW)

In recent years, the state of Rhode Island has established a variety of incentives to spur the development of renewable energy in the state. The Renewable Energy Standard is the overarching policy which guarantees a market for renewable energy by requiring electrical distribution companies to purchase a certain amount of it per year. Other incentives foster distributed generation, net metering, interconnection, and tax incentives.

Renewable Energy Standard (R.I. Gen. Laws § 39-26-1 et seq.): The Renewable Energy Standard, enacted in 2004, requires all electricity distribution companies operating in Rhode Island to purchase a certain percentage of electricity sold for retail consumption from eligible renewable energy resources. That percentage increases each year, starting at 3% in 2007 and stabilizing at 16% in 2019. The Renewable Energy Standard is implemented by the Public Utilities Commission, which tracks renewable electricity usage through tradable credits called New England Power Pool (NEPOOL) certificates. NEPOOL certificates accrue to wind, solar, hydro, or other renewable energy producers at the time of production and may be sold by the producer to an electricity distributor. Certificates provide project owners with a marketable product supplementing the marketable electricity produced by the turbine.

Electricity distributors may also fulfill the requirements of the Renewable Energy Standard by purchasing Alternative Compliance Payments or by banking credits from one year to the next. The PUC establishes the Alternative Compliance Payments rate on January 31st of each year; this rate effectively caps the rate at which renewable electricity producers may sell certificates to distributors, since any certificate offered would be turned down in favor of purchasing Alternative Compliance Payments.

Long Term Contracting Standard (R.I Gen. Laws § 39-26.1-1): Rhode Island instituted the Long Term Contracting Standard in 2009 to facilitate the creation of long-term contracts between electricity distribution companies and developers of renewable energy resources in Rhode Island. It requires electricity distributors operating in Rhode Island to enter into 10- to 15-year contracts with new renewable energy producers (defined as those who have not yet secured investments necessary for construction). Each distributor in the state is required to purchase a total of 90 MW (nameplate capacity) by December 30, 2013, starting with 25% of this total amount per year in 2010 and increasing by another 25% per year thereafter. Contracts must be approved by the PUC, and must document benefits to the Rhode Island economy. The Long-Term Contracting Standard provides demand for new renewable energy projects, and allows for a predictable return on investments through long term contracts.

Distributed Generation Standard Contracts (R.I. Gen. Laws § 39-26.2-1 et seq.). The Distributed Generation Standard Contract of 2011 facilitates the interconnection of numerous small-scale (under 5MW) electricity producers to the main grid, known as distributed generation. It applies to all forms of renewable energy. Similar to the Long Term Contracting Standard, it establishes a minimum annual electricity purchase, but with the added specification that the purchase be from distributed generation renewable energy projects. Those purchases must total above 5 MW (nameplate capacity) per electricity distributor by the end of 2011, 20 MW in 2012, 30 MW in 2013, and 40 MW in 2014. Unlike the Long-Term Standard Contracts, the Distributed Generation Standard Contract makes operational wind turbines eligible to apply for contracts. The law also establishes a Distributed Generation Standard Contract Board to set annual ceiling prices and targets for each type of renewable energy, and a Contract Working Group to develop the standard contracts. Contracts are required to purchase all energy supplied by an eligible facility and to have durations of 15 years at a fixed rate.

Net Metering (R.I. Gen. Laws 39-26.4-2): Both the Long Term Contracting Standard and the Distributed Generation Standard Contracts apply only to commercial renewable energy projects that make all of the electricity they produce available for purchase. In contrast, Rhode Island's 2011 Net Metering law enables renewable energy project owners who produce electricity for consumption at the site of production to connect to the grid and receive retail credit for at least a portion of any excess electricity they generate. Net Metering can apply to any type of renewable energy. To be eligible for net metering, an energy facility must produce no more than 5 MW (nameplate capacity) and must be designed and sized to produce an amount of electricity equal to or less than the net metering customer's annual electricity usage at the site. This prevents developers from over-sizing their projects in order to sell electricity at the retail price, which would result in an increase in rates paid by other electricity customers. Municipal projects are exempt from this latter provision. There is a statewide cap on total net-metering of 3 percent of peak load, and at least 2 MW out of this maximum are reserved for projects 50 kW in nameplate capacity.

Distributed Generation Interconnection (R.I Gen. Laws § 39-26.3): Rhode Island's 2011 Distributed Generation Interconnection law facilitates investment in renewable energy projects by enabling potential investors to estimate the cost of connecting to the grid before starting a project. To make this estimate, developers may choose between an impact study and a feasibility study; an impact study relies on engineering tools, while a feasibility study relies on prior knowledge and judgment held by the relevant electricity distribution entity. In both cases, the electricity distribution company expected to buy the electricity produced at the site is required to provide "good faith estimations" of the eventual cost of interconnection. Fees and schedules for these studies are based on the size of a project and on whether the project is residential or non-residential. Distributed generation interconnection applies to any form of renewable energy.

Renewable Energy Coordination Act (42-140.3): The Renewable Energy Coordination Act of 2008 established the Renewable Energy Development Fund and the Municipal Renewable Energy Investment Fund, which apply to all forms of renewable energy. Both are overseen by the Economic Development Corporation (EDC), and selection of recipients is based on technical feasibility, financial viability, anticipated renewable energy production and cost, project management capabilities and time to market of the project. The Renewable Energy Development Fund is funded through Alternative Compliance Payments provided for in the Renewable Energy Standard (see above), while the Municipal Renewable Energy Investment Fund is funded through a required surcharge on retail electricity of 0.3 mills/kilowatt-hour ($^{1}/_{1000}$ of a dollar per kilowatt hour) between 2003 and 2013. The Renewable Energy Development Fund provides assistance for private expansion and development of renewable energy projects in Rhode Island, while the Municipal Renewable Energy Investment Fund provides assistance for public projects of the same nature. Both programs provide funds in the form of loans, grants, and recoverable grants.

Tax Benefits (R.I Gen. Laws § 44-3-2): Rhode Island authorizes city or town councils to pass ordinances at their discretion exempting any renewable energy system located within the town or city from property taxes. Tax exemption is more likely to apply to commercial projects than residential projects.

6. CONCLUSIONS AND CONSIDERATIONS FOR MOVING FORWARD

6.1 Summary of RESP Wind Energy Findings

Although it is clear from the RESP wind resource assessment (Chapter 1 Section 2) that Rhode Island does not have the physical geography or wind resources to support the development of large land-based wind farms comprised of tens or hundreds of turbines, it is also apparent that some parts of the state – primarily coastal areas – do experience wind speeds sufficient to support some production of commercial wind power. In addition, the extent of area suitable for commercial wind power production may increase as wind turbine generation technology improves. Thus, it is expected that many Rhode Island communities will continue to look to wind power as a way to combat rising fuel costs, decrease dependence on imported fuels, expand jobs in the renewable energy sector, and reduce greenhouse gas emissions.

However, the task of harnessing wind energy potential is complicated by the fact that the windiest parts of the state tend to also be densely populated or important wildlife habitat. Given the existing uses of these areas, care must be taken to avoid and/or minimize potential negative impacts. Proper siting is the best known antidote to potential negative impacts associated with wind energy development. Ch. 1 Table 19 summarizes the major wind related findings of Volume I and II, potential impacts and predicted occurrence in Rhode Island identified through the RESP process which provide useful context and considerations moving forward in the drafting of statewide siting guidelines, or designing municipal review procedures for proposed projects, or wind energy ordinances.

Ch. 1 Table 19. List of the major findings, potential impacts and predicted occurrence in Rhode Island as identified through the RESP

Issue	RESP Findings
Wind Resources	• Rhode Island wind speeds reflect the fact that the state is relatively flat, and lacks the increases in wind speed associated with high elevations. • Much of the inland portion of Rhode Island is forested, contributing to a high degree of surface roughness that slows wind speeds in that portion of the state. • The highest wind speeds in Rhode Island tend to be close to the coast, due to this area's proximity to the flat expanse of the ocean. • The U.S. Department of Energy estimates that wind energy production currently requires wind speeds greater than 7 m/sec (16mph) at 80m (262 ft). According to previous modeling by AWS TrueWind, Rhode Island has an average wind speed of 5.5-6.0 meters/sec (12-13mph) at 80m (262ft). • Coastal regions of the state have higher wind speeds, measuring an average of 6.5-7.5 meters/sec (15-17mph) at 80m (262ft). Block Island has the highest wind speeds in the state, at 8-9 meters/sec (18-20mph) at 80m (262ft). • There is more seasonal variation in wind speeds closer to the shore, but greater daily variation in wind speeds as one moves further inland.
Structural Failure or Ice Throw	• Structural failure of wind turbines is rare but not impossible. • Publically available data on wind turbine failure rates is very limited. Therefore, calculating failure rates for current wind turbines technology can be difficult, as not all incidents are reported, and there is no centralized regulatory body charged with compiling and verifying failure incidents in the United States. • If a blade fragment detaches from a turbine, the location of landfall is controlled by the angular velocity of the rotor, the position of the breaking point on the blade, and the size of the thrown piece. This relationship can be used to identify an appropriate setback from homes and other populated sites given different risk tolerances. • Similar to other structures icing may occur on wind turbines. When ice falls or is flung from a moving blade, it can potentially become dangerous. • Rhode Island experiences weather conditions conducive to icing of turbine blades about 0-2 times annually. During those times, there is a risk of ice throw, particularly if a turbine continues to operate. • The potential risk associated with ice throw can be minimized through setbacks, shutdown procedures, and ice detection mechanisms.

Issue	RESP Findings
Noise	• Wind turbines produce noise through the rotation of blades and operation of the generator. • Turbines can produce white noise (broadband noise), tonal noise, impulsive noise ("swishing"), low-frequency noise, and infrasound. • Background noise is an important factor to consider when predicting the acoustic impacts of wind turbines. Where ambient noise levels are high, as in densely populations or industrial zones, turbine noise is less audible. • Noise assessment studies that include ambient noise levels and turbine noise levels at the source, together with a sound propagation model can be useful in determining noise impacts during the review process of a proposed project. • Wind turbine noise can be considered annoying. This is a highly subjective and individualized impact, and can be a significant nuisance to those people bothered by it.
Shadow Flicker	• Moving wind turbine blades can cause a shadow flicker effect when positioned within the line of sight between the sun and a viewer. • Given high enough exposure, shadow flicker can be considered annoying and can cause disruption to daily life. It does not, however, induce seizures, as had previously been hypothesized. • Shadow flicker takes place only when the sun is shining and when the blades are facing the sun resulting in a shadow. In an average year in Rhode Island, slightly over half of the days each year are sunny or partly sunny. • The shadow flicker effect is visible only at certain times of the day and the year, when the sun is at a low angle in the sky. • The zone affected by shadow flicker can be predicted using computer models. Unobstructed shadows in our latitudes will typically have a bow tie or flattened cross shape. • Predictive models can be used to establish setback zones to minimize impacts of shadow flicker on nearby residents.
Electro-magnetic Interference	• Like other tall structures, wind turbines have the potential to interfere with electromagnetic waves, such as those used by television, cell phones, radio, and scanning telemetry systems. • Turbines can cause both blocking and reflection of these signals when located in the line of site between transmitter and receiver. • Electromagnetic occurrence is less of an issue with newer wind turbines that are not made of metal. • Appropriate siting of wind turbines to avoid installations in the sight lines of affected technologies will minimize any impacts.

Issue	RESP Findings
Bird and Bat Impacts	• Wind turbines can affect birds and bats by causing collisions, displacement, barrier effects, and habitat loss. • Compared to other anthropogenic sources such as buildings, power lines and automobiles, bird collisions with wind turbines are relatively low. • Bats can also suffer from barotrauma, a form of internal tissue damage that occurs when bats experience a sudden drop in pressure when flying behind a spinning turbine rotor. • Most bird mortalities resulting from collision with wind turbines occur during spring and fall migrations. Most bat mortalities occur from mid-summer to fall. • Construction of turbines in important bird or bat habitat can cause habitat fragmenting and/or lead to avoidance behavior. • The four main habitat types used by birds in Rhode Island are grasslands, scrub-shrub, forests, and coasts. Some habitats are more important and/or vulnerable that others; each may require a different form of protection when siting wind turbines • Vulnerable species may represent a priority concern when siting wind turbines. Rhode Island has two federally listed threatened bird species and one federally listed endangered bat species. In addition, 53 bird species are listed as endangered, threatened, or of concern by the state. • Establishing buffers around known nests and/or key habitats used by vulnerable species may be necessary to protect these species from the effects of wind turbines.
Historic and Cultural Resources	• The environment around a wind turbine may contain historic buildings, artifacts, and landscapes; sites of cultural importance to Native American tribes; and sites valued for their scenic or recreational value. Historic sites are located throughout Rhode Island. • Wind turbines can cause both direct and indirect effects on historic and cultural sites when not sited carefully. • As historic and cultural sites are often unique and irreplaceable, many are legally protected by the federal National Register of Historic Places, the Rhode Island State Register of Historic Places, municipal historic districts, and/or the Narragansett Indian Tribe Historic Preservation Office. • Consultation with the Rhode Island Historical Preservation & Heritage Commission is required for land-based wind energy projects funded by federal, state, or local funding or if they require state or federal permits. Projects which are entirely private undertakings are not subject to review unless a federal or state permit or license is required. Consultation and review will determine whether the proposed project will harm a resource which is on or eligible for the National Historic Register.
Visual/ Aesthetics	• Wind turbines are large and can be visible from a distance. Some people may consider wind turbines a negative impact on the landscape, while others may find that they enhance a landscape. • The visual impact of wind turbine will likely be greatest in areas valued for their scenic qualities. • Visual impacts can be assessed through community review of visual simulations of what a proposed turbine would look like in a given setting.

Issue	RESP Findings
Property Value Impacts	• The effect of wind turbines of property values can be a prime concern among community members during the wind turbine siting process. • The potential for wind energy facilities to cause impacts on nearby property values has been assessed through analog studies, stated preference surveys, studies of real estate values or sales data, and surveys of expert practitioners. • Analog studies attempt to anticipate the property-values effects of wind energy projects by looking at impacts associated with other land uses, such as utility transmission lines, highways, and power plants. These other uses have been found to result in declines in property value of anywhere from 0% to 16%, which may represent an upper bound on the effects of wind turbines, since turbines are often considered less undesirable than these other uses. • Stated preference surveys ask residents living near existing or proposed wind turbines to discuss perceived or anticipated effects of wind turbines on property values. This chapter reviews three stated preference surveys; all indicate some evidence for a perceived or anticipated decline in property values due to existing or proposed wind turbines. • Studies of real estate values or sales data rely on statistical methods to compare the values of homes at varying distances from a wind energy project, values inside/outside the viewshed of a project, or values before/after a project was installed. This chapter reviews 15 such studies. Of the studies reviewed, nine failed to find evidence of a negative impact of wind energy projects on property values, three found some evidence for negative impacts, and two found both negative and positive impacts. In addition, two studies found evidence showing that the anticipation of a wind turbine has a more negative effect on home sales prices than the wind turbine once constructed. • Expert opinion surveys rely on the judgment of real estate agents, appraisers, town officials, or surveyors to estimate possible impacts of wind energy projects on property values. This chapter reviews three expert opinion surveys. Two found some evidence that experts associate a negative impact on property values with the presence of a wind energy project; the third found evidence that experts do not believe such a link exists. • Anecdotal evidence offered by homeowners and others whose personal experience has given them insight into the relationship between property values and wind turbines, albeit on a very small and individualized scale. Because of their small sample size, these accounts cannot distinguish between the influence of wind turbines and other factors affecting property values. Nonetheless, these accounts may provide useful information for improving case-specific understandings of how property values change near wind turbines. Like large-scale market analyses, most anecdotal accounts refer to wind farms, not single turbines. • Most studies and anecdotal accounts to date focus on multi-turbine wind farms in rural areas. Their findings may not be 100% transferable to situations like Rhode Island, where population density is high and single-turbine projects are the norm. • Compensation of property owners affected by wind energy projects by project developers is an emerging approach to dealing with the potential for negative effects on property values. Only a few instances are known, and few details are available.

6.2 Further Research Needs Identified through the RESP Process

In addition to the findings of Ch. 1 Table 19, the RESP process has also identified priority topic areas for further study. While there has been a large amount of research conducted on land-based wind energy and its impacts, to date much of the research has focused on large wind farms developed in rural areas. Less research is available on projects set in residential areas consisting of one or a few turbines. After conducting a review of the best available science, and compiling stakeholder feedback throughout the RESP process, two areas were identified that would benefit from additional research, especially research specific to Rhode Island:

- **Rhode Island-centered investigation into the impacts of wind turbines on nearby property values.** Most studies of wind energy impacts on property values to date have focused on large wind farms in rural areas. In response to stakeholder concerns, the RESP held a work session on September 20, 2012 with expert Ben Hoen, Principal Research Associate from the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory to discuss existing knowledge on the impacts of wind turbines on residential property values (see Chapter 5 Section 2.7 for more detail, notes and presentation can be obtained online at http://seagrant.gso.uri.edu/resp/documents.html#shmeeting). Following the review of existing research on this topic in other regions of the U.S., participants stressed the importance of conducting new kinds of analysis, while also tailoring analyses to a Rhode Island context, including:
    - Study the effects of wind energy facilities on properties at distances under one mile, including those in very close range (e.g., under 1,000 ft) to a turbine.
    - Study the effects of single-turbine facilities (i.e., not wind farms) on property values.
    - Conduct research on possible impacts of wind turbines on sales volume, not just sales values, of nearby properties.
    - Examine relationships between the existence of wind turbines and the length of time that nearby properties are on the market.
    - Look for changes in appraised property values, not just sales prices.

  As a follow up to this work session, a URI research team has submitted a proposal to OER for further research on property value impacts using an existing database of Rhode Island real estate values.
- **Acoustic impacts of operating turbines, including infrasound.** Acoustic impacts from wind development in residential areas was consistently expressed as a concern to stakeholders throughout the RESP process, and in particular the effects of infrasound. While research on the acoustics of wind turbines have been conducted elsewhere in the country, it would be useful to collect acoustic data at turbines currently operating in Rhode Island, including turbines installed in urban, industrial, residential and rural areas. In addition to the data collected, the protocol used to determine ambient noise levels and the impact of the turbine noise at various times of day may be useful to cities and towns who may in the future want to require wind project developers to monitor acoustic impacts after installation. It is our understanding that after the conclusion of the RESP, OER is developing plans for further research on this topic; we'd recommend that the aforementioned points are considered if possible during the planning of this research.

While there are other possible research topics that could benefit from additional study, these two topics represent those most suggested by stakeholders during the RESP process.

6.3 Considerations for Future Management from the RESP Process

The goal of the RESP was not to promote renewable energy or to determine the best spots in the state to site renewable energy projects. Rather, in light of Rhode Island's Renewable Energy Standard mandate to obtain 16% of the state's electricity from renewable sources by 2019, and the growing interest in renewable energy around the state, the RESP set out to collect and synthesize information that would serve decision makers and other stakeholders as they make siting and permitting decisions in their own communities.

As municipalities move forward in designing permitting frameworks for wind energy projects and the state considers wind energy siting guidelines the analysis and tools produced through the completion of the RESP reports and the creation of online siting tools at RIEnergy.org will serve as a valuable resource of information. Ultimately however, the appropriate siting of land-based wind energy projects requires both sound science and also subjective judgment that a proposed project is in line with the goals and values of a municipality, especially when setting limits on shadow flicker impacts, noise impacts, and safety setbacks. Because each city and town in Rhode Island may differ in characteristic (e.g. ambient noise levels, population densities, etc.) and values, the standards and review process for land-based wind energy development may vary by location. As a result, there is no one size fits all approach to wind energy siting in Rhode Island.

To aid in the municipal review process and the creation of state land-based wind siting guidelines, the following sections provide a summary of the types of studies or analyses that municipalities may want to consider requiring of project applicants during the permitting process, as well as a list of siting and mitigation options that could be useful in creating wind siting guidelines for the state.

6.3.1 Possible Studies or Analyses for Impact Assessment or Monitoring

Understanding the particular impacts of a project during the review process can be informed through a number of impact assessment studies. In addition, post-construction monitoring can also be used to ensure predictions during the review process were accurate, or to determine if increased mitigation measures are necessary. Below is a list of pre-construction assessments and post-construction monitoring studies that a municipality may want to consider when determining what information or data is required during the review and permitting process. While the list below of studies is not exhaustive, and there may be additional studies a municipality may want to require of project developers depending on site specific conditions, this list does represent studies frequently used to assess the effects of a project. Furthermore, whether or not the results of these studies and assessments are deemed acceptable by a municipality will depend on siting criteria established by each city or town.

Preconstruction/Permitting Review

- **Wind Resource Assessment**- Wind resource assessments are conducted to ensure that there is sufficient wind resources at a proposed site to be profitable. Data collected should be collected at hub height and cover multiple seasons to account for seasonal variation in wind speeds and direction. For municipalities interested in determining the wind resources available in their city or town, URI's SODAR unit will be available.
- **Shadow Flicker Analysis-** Shadow flicker impacts can be modeled to determine how many hours of flicker (under the worst case scenario) surrounding properties may experience.
- **Noise Study-** Based on the specifications of the proposed turbine and ambient noise levels at the proposed site, predictive models can be used to determine noise impacts to surrounding properties.
- **Environmental Assessment:** Environmental assessments may be useful to characterize the habitat and wildlife species present at a particular site. In particular, birds, bats, ground dwelling species, presence of 'species of concern' or critical habitat for these species, wetlands, presence of plant communities of concern. While not all projects may require such an assessment, if wildlife or environmental impacts are a concern this may provide valuable information during the siting and review process. Federally funded projects may require a formal environmental review under the National Environmental Policy Act (NEPA). State environmental permits may be necessary if proposed site may impact wetlands or the coastal zone.
- **Visual Assessment-** Visual simulations using photographs taken by a trained technician in clear conditions from several unobstructed publically accessible locations (especially historic and scenic resources).
- **Consultation with the Rhode Island Historical Preservation & Heritage Commission** (required for projects with federal, state, or local funding or if state or federal permits are required)
- **Federal Aviation Administration (FAA) Determination** (required if structure is over 200 ft)
- **Interconnection-** The Interconnection Review Process with National Grid will help determine if a proposed site has the grid-related infrastructure necessary to support a proposed project.

Post Construction Monitoring

- **Establish a Registry for Positive and Negative Complaints**-
- **Noise** - Noise measurements of the turbine operating at various times of day, during different seasons and wind speeds and at various distances from the turbine may help ensure the noise produced by the turbine(s) is within specified noise levels.
- **Shadow Flicker**- While worst case scenarios of shadow flicker impacts can be modeled prior to installation, it may be useful to monitor actual shadow flicker occurrence in order to determine if mitigation measures are necessary.

- **Bird or Bat Mortality-** In areas where bird or bat mortality is a concern, post construction monitoring may be useful to gauge the severity of this impact. Paton et al. (2012) in Volume II of the RESP document provides greater detail on when monitoring may be appropriate and what methodology can be used to most effectively assess a project's impact to birds and bats.

6.3.2 Considerations for Wind Siting Guidelines

Creating statewide guidelines and recommended setbacks related to the potential effects of land-based wind energy development (Ch. 1 Table 19) is challenging as each city and town in Rhode Island is unique. In addition, in some cases guidelines (such as noise and shadow flicker impacts) are quality of life issues, not solely based on scientific findings but also on the best judgment of a municipality.

Moving forward, as the "Renewable Energy Siting Guidelines, Part 1: Interim Siting Factors for Terrestrial Wind Energy Systems" produced by the Statewide Planning Program's Wind Energy Siting Working Group are examined further the following siting considerations in Ch. 1 Table 20 may be useful.

Ch. 1 Table 20. List of Siting and Mitigation Options to Minimize Impact of Land-Based Wind Energy Development

Impacts or Issues	Options to Minimize Impacts of Wind Energy Development	
	Siting	**Mitigation**
Structural Failure	• Setbacks from residential homes, roads, or other buildings and infrastructure • Setbacks may include a set minimum distance or a distance based on the height of the turbine	• Safety system to monitor turbine operations and alert when possible malfunctions • Safety shutdown procedures
Icing	• Setbacks from residential homes, roads, or other buildings and infrastructure • Setbacks may include a set minimum distance or a distance based on the height of the turbine	• Safety shutdown procedures • Ice detection mechanisms
Shadow Flicker	• Shadow flicker analysis of proposed site to determine shadow flicker effects on adjacent properties • Predictive model at RIEnergy.org can be used to map impact zones • Establish a maximum number of hours per day and/or hours per year in which a wind turbine is allowed to produce shadow flicker. When setting limits however, it is important to define how flicker impacts will be measured (e.g. at property line? On adjacent building, road, etc.?)	• Turbine shut down once the maximum shadow flicker per day or year has been reached • Landscaping to block flicker on surrounding properties (i.e. trees, shrubs, walls) • Light blocking shades to potentially affected residents
Electromagnetic Signal Interference	• Siting of wind turbines to avoid sight lines of affected technologies • Review of communication towers in the area to ensure no sight lines are being blocked	
Acoustic Impacts	• Model acoustic impacts of the installed technology based on turbine specifications and ambient noise levels at the proposed site to assure noise impacts do not have significant adverse impact on neighbors or adjacent land users. • Municipalities with preexisting noise ordinances my require installed to comply with regulations already in place, unless waived by the municipality on a case-by-case basis • Set a maximum acceptable decibel level, or change above ambient noise levels and require wind turbine to cease operations if that level is exceeded.	• Require wind turbine to cease operations if that level is exceeded.

Impacts or Issues	Options to Minimize Impacts of Wind Energy Development	
	Siting	**Mitigation**
Avian and Bat Impacts	• Environmental assessment performed by third party of surrounding habitat and species present • Avoidance or setbacks around known nests and/or key habitats, particularly those used by endangered or threatened species • Following the guidance provided in Paton et al. 2012 (Volume II) and the USFWS guidelines for siting and monitoring avian impacts	• Shut down of turbine or raising the cut-in speed during periods of migration through the area • Altering turbine coloring or lighting to lessen the attraction of birds
Cultural and Historic Impacts	• Consultation with the Rhode Island Historical Preservation & Heritage Commission is required for projects funded by federal, state, or local funding or if they require state or federal permits. Projects which are entirely private undertakings are not subject to review unless a federal or state permit or license is required. Consultation and review will determine whether the proposed project will harm a resource which is on or eligible for the National Historic Register.	
Visual Impacts	• Visual impact assessment and simulations • Community input on the visual impacts using simulations	
Property Value Impacts	• Use of safety setbacks or limits on noise and shadow flicker will help minimize any property value impacts	• Compensation of property owners if negative property value impact is determined

6.3.3 Municipal Wind Ordinances

As greater numbers of municipalities draw up formal approaches to wind energy siting within their borders, the specifics will be locally informed and will vary greatly from town to town. Interest in wind energy, availability of wind resources, and constraints on wind energy development are a few of the factors contributing to local decisions on whether and where to pursue wind energy development. Municipal participation in the RESP stakeholder process indicated that priorities differ widely across Rhode Island communities. For some towns, preservation of historic or scenic vistas takes high precedence, while others may be more concerned about offsetting current municipal energy bills through net metering. Both the likelihood of impacts and the determination of an acceptable level of impact are expected to vary by municipality, and there is no one-size-fits all approach to wind energy siting.

Ch. 1 Table 21 lists the different permitting options municipalities may choose from when deciding how to regulate wind energy development in their city or town.

Ch. 1 Table 21. Municipal Options for Regulating Wind Energy Development

<table>
<tr><th>Option</th><th>Definition/Example</th><th>Relevant Considerations</th></tr>
<tr><td>Permitted use</td><td>Municipalities may devise a single ordinance that will address standards for all types of wind energy projects with detailed references to different types of projects within each section. A project is acceptable as long as it meets design standards.</td><td rowspan="3">Municipalities may choose to specify different permitting arrangements based on the scale of the project (e.g., small, medium, or large) and the zoning designation of the surrounding area (e.g. rural, residential, commercial, or industrial). As turbine size and population density increase, so do the benefits of requiring a special use permit above and beyond what is required for conventional permitted uses. Special use permits can offer more nuanced municipal oversight of a project than a general permitted use permit. An overlay wind energy zone may save time during the permitting process, but offers less control over each development on a case-by-case basis.</td></tr>
<tr><td>Special use permit, conditional permit</td><td>The “special use permit” zoning process granted to municipalities through RI General law Section 45-24-42 of the RI Zoning Enabling Act. Special use permits allow for a regulated use pursuant to meeting certain performance criteria and procedures for the use and are issued by municipal zoning boards of review. The permit is granted if the applicant demonstrates that the use would not be injurious to the public health, safety and welfare. A special use permit is not to be confused with a dimensional variance, which concerns only the physical setback requirements of a particular parcel. Development is permissible only under the conditions identified in the permit.</td></tr>
<tr><td>Zoning overlay</td><td>Superimposes a zoning category (such as a special wind energy zoning area) onto a larger base zone. Conditions pertaining to development are uniform throughout all lands receiving this designation, and are complementary to the underlying zoning designations of these lands.</td></tr>
</table>

If a municipality decides to develop land-based wind energy ordinance, a review of similar ordinances used in cities and towns throughout the country have identified some common components:

- *Purpose and Applicability:* This section outlines the purpose of the ordinance and outlines what types of projects it is intended to regulate.
- *Definition Section:* This section allows the municipality to craft definitions of technologies, impacts, and requirements that reflect local understandings and priorities.
- *Permitting Procedure*: In this section, a municipality may list required documents (e.g., site plan, blueprints, documentation of the components such as panels, mounting systems or

turbine structures, proof of liability insurance, property lines and physical features around the project site, and an operations and maintenance plan) or simply state that there must be a general compliance with local, state, and federal rules and regulations. Some municipalities (e.g., North Carolina) also require developers to produce financial surety to cover the cost of turbine removal in the form of a bond, escrow, or other commitment. Municipalities may also include a list of impact assessment studies required with the application (see Section 6.3.1)

- *Abandonment and Decommissioning Procedure:* Decommissioning refers to planned removal of a wind energy facility, while abandonment is unforeseen. Requirements may be made for notice, removal plans, financial guarantees and a date by which turbines must be removed. The plan may also call for the owner to restore the site to its original status.
- *Mitigation Measures:* In this section, a municipality may specify required measures to mitigate potential acoustic, shadow flicker, property values, and environmental impacts associated with wind turbines. Mitigation measures typically include setbacks, maximum hours per day or year of shadow flicker, signage and lighting limitations, public safety procedures, and may also require proof of liability insurance (see Ch. 1 Table 20).

6.4 Moving Forward

As the dialog regarding land-based wind energy development in Rhode Island advances, continued involvement of all stakeholders, from both the public and private sectors, will be necessary. The RESP process has contributed greatly to this ongoing discussion by providing a forum for the people of Rhode Island to learn about this topic and share their issues, concerns and recommendations. In addition, as a result of the RESP the state now has numerous scientific resources, containing Rhode Island specific data to inform the decisions surrounding renewable energy. Throughout the RESP process, the public was heard and their comments were thoughtfully considered during the completion of the RESP products(all comments received and responses are available online at http://seagrant.gso.uri.edu/resp).

Moving forward, the Rhode Island Office of Energy Resources is committed to continued work on the topic of renewable energy and further investigations into this topic. Following the RESP, the Rhode Island Office of Energy Resources and Division of Planning, Statewide Planning Program will be updating the existing Rhode Island State Energy Plan (State Guide Plan 781) and creating an overarching strategy for managing Rhode Island’s energy using safe, reliable, least-cost, environmentally sound, sustainable, and where appropriate, in-State resources. This planning process will engage both public and private stakeholders, and encompass all energy sectors in the state (e.g. residential, commercial & industrial, municipal, power generation, and transportation) including both onshore and offshore renewable energy. The findings and tools of the RESP will be an important resource in this comprehensive energy planning process, as land-based renewable energy development in Rhode Island is examined in a broader context, with all other energy sources.

7. REFERENCES

Acoustic Ecology Institute. 2009. Special Report: Wind Turbine Noise Impacts. <http://www.acousticecology.org/docs/AEI_WindFarmNoise_2009inReview.pdf>.

Acoustic Ecology Institute, Wind Farm Noise 2012: Science and Policy Overview (Compiled by Jim Cummings). < http://www.acousticecology.org/wind/winddocs/AEI_WindFarmNoise2012.pdf>.

Anderson, R., Neumann, N., Tom, J., Erickson, W.P., Strickland, M.D., Bourassa, M., Bay, K.J., and Sernka, K.J. 2004. Avian monitoring and risk assessment at the Tehachapi Pass Wind Resource Area. Period of Performance: October 2, 1996 - May 27, 1998. Report for the National Renewable Energy Laboratory: 102.

Arnett, E.B., Brown, W.K., Erickson, W.P, Fiedler, J.K, Hamilton, B.L, Henry, T.H., Jain, A., Johnson, G.D., Kerns, J., Koford, R. R., Nicholson, C. P., O'Connell, T. J., Piorkowski, M. D., and Tankersley, R. D., JR., 2009. Patterns of bat fatalities at wind energy facilities in North America. *Journal of Wildlife Management* 72(1): 61-78.

August, P. V., R. W. Enser, and L.L. Gould. 2001. Vertebrates of Rhode Island, Volume II of the biota of Rhode Island. Rhode Island Natural History Survey, Kingston, RI.

AWEA (American Wind Energy Association). 2009. Wind Energy Basics - What is "Capacity Factor"? May 5, 2012. <http://archive.awea.org/faq/wwt_basics.html#What%20is%20capacity%20factor>.

AWEA (American Wind Energy Association). 2008. Wind Energy Siting Handbook. Available online at: May 3, 2012. <http://www.awea.org/sitinghandbook/download_center.html.>

Baerwald, E.F., D'Amours, G.H., Klug, B.J. and Barclay, R.M.R. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology 18: 695-696.

Baerwald, Erin F., Genevieve H. D'Amours, Brandon J. Klug and Robert M.R. Barclay. 2009. Barotrauma is a significant cause of bat fatalities at wind turbines**.** Current Biology 18(6): R695-R696.

Barclay, R.M.R., Baerwald, E.F. and Gruver, J.C. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85: 381-387.

Baring-Gould, I. 2006. Ice and snow – and the winds do blow. Proceedings of the National Wind Coordinating Committee Siting Technical Meeting, Washington, DC.: 56-59. <http://www.nationalwind.org/events/siting/proceedings.pdf>.

Barrios, L. and Rodriguez, A. 2004. Behavioral and environmental correlated of soaring-bird mortality at on-shore wind turbines. Journal of Applies Ecology 41: 72-81.

Been, Vicki. 1993. Compensated siting proposals: is it time to pay attention? *Fordham Urban Law Journal* 21(3): 786-826.

Bishop, Ian. 2002. Determination of thresholds of visual impact: the case of wind turbines. *Environment and Planning B: Planning and Design.* 9: 707-718.

Bittner-Mackin, E. 2006. Excerpts from the final report of the Township of Lincoln Wind Turbine Moratorium Committee.

Bolin, K., Bluhm, G., Eriksson, G. and Nilsson, ME. 2011. Infrasound and low frequency noise from wind turbines: exposure and health effects. *Environmental Research Letters* 6 (2011) 035103 (6pp).

Bond, S. 2008 Attitudes towards the development of wind farms in Australia. *Journal of Environmental Health Australia.* 8(3): 19-32.

Braunholtz, Simon. 2003. Public Attitudes Towards Windfamrs: A Survey of Local Residents in Scotland. Prepared for Scottish Executive Social Research. MORI Scotland, Edinburgh. 39 pp. Available online at: http://www.scotland.gov.uk/Resource/Doc/47133/0014639.pdf. Last accessed October 20, 2012.

Brinkmann, R., Schauer-Weisshahn, H. and Bontadina, F. 2006. Survey of possible operational impacts on bats by wind facilities in Southern Germany. Report ordered by the Administrative District of Freiburg - Department 56 Conservation and Landscape Management: 63.

California Energy Commission. 2006. Permitting setback requirement for wind turbines in California. PIER Interim Project Report prepared by the California Wind Energy Collaborative. <http://www.energy.ca.gov/pier/project_reports/CEC-500-2005-184.html>.

Canning, George and L. John Simmons. 2010. Wind Energy Study - Effect on Real Estate Values in the Municipality of Chatham-Kent, Ontario. Prepared for Canadian Wind Energy Association. Canning Consultants and John Simmons Realty Consultants, Ontario, Canada. 85 pp. Available online at: http://www.samsungrenewableenergy.ca/sites/default/files/pdf/haldimand/PropertyValuesConsultingReportFebruary42010%5B1%5D.pdf. Last accessed October 14, 2012.

Carrete, M., b Sanchez-Zapata, J.A., Benitez, J.R., Lobon, M., Donazar, J.A. 2009. Large scale riskassessment of wind-farms on population viability of a globally endangered long-lived raptor. Biological Conservation doi: 10.1016/j.biocon.2009.07.027.

Carter, J. 2011. The Effect of Wind Farms on Residential Property Values in Lee County, Illinois. Thesis Prepared for Masters Degree. Illinois State University. 35 pages. Available online at: http://renewableenergy.illinoisstate.edu/wind/publications/2011%20Wind%20Farms%20Effect%20on%20Property%20Values%20in%20Lee%20County.pdf. Last accessed October 14, 2012.

Cassidy, Patrick. 2009. *Cape Cod Online*. March 26, 2012. <http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20091013/NEWS/910130312>.

Cattin et al. 2005. WIND TURBINE ICE THROW STUDIES IN THE SWISS ALPS. Cattin, et. Al. 2005 <http://www.meteotest.ch/fileadmin/user_upload/Windenergie/pdfs/paper_ewec2007_cattin_final.pdf>.

Chouard, C.H. 2006. *Effects of wind Turbines on Human Health* (Le retentissement du fonctionnement des eoliennes sur la sante de l'homme). National Academy of Medicine (France).

Colby, W. David, Robert Dobie, Geoff Leventhall, David M. Lipscomb, Robert J. McCunney, Michael T. Seilo, and Bo Søndergaard. 2009.*Wind Turbine Sound and Health Effects, an Expert Panel Review*. AWEA, CANWEA. May 12, 2012. <http://www.windpoweringamerica.gov/filter_detail.asp?itemid=2487>.

Coles, R W & Taylor, J (1993). Wind Power and Planning – The Environmental Impact of Windfarms in the UK. Land Use Policy 10(3):205-226.

Cownover, Brad, Rob Thayer, Robert Ryan, and Stephen Sheppard. 2010. Wind Energy on the Horizon.<https://docs.google.com/viewer?a=v&pid=explorer&chrome=true&srcid=0B3dEkGBeMfqDY2Q0YmY2YTctM2M3Yy00YjlkLTg2ZTgtY2JkOGQxOGUwMDBh>

Cryan, P.M. 2008. Mating behavior as a possible cause of bat fatalities at wind turbines. Journal of Wildlife Management 3: 845-849.

Cryan, P.M. and Brown, A.C. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation doi: 10.1016/j.biocon.2007.05.019.

DeSante, D. and P. Pyle. 1986. Distributional checklist of North American birds. Volume 1: United States and Canada. Artemesia Press, Lee Vining, CA.: 442.

Devereux, C.L., Denny, M.J.H. and Whittingham, M.J. 2008. Minimal effects of wind turbines on the distribution of wintering farmland birds. Journal of Applied Ecology 45: 1689-1694.

Drewitt, A.L. and Langston R.H.W. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29-42.

Elkinton, M., and Wright, S. 2007. Proposed Fairhaven wind power project: Shadow flicker analysis. Renewable Energy Research Laboratory, University of Massachusetts Amherst.

Elliott, D.L., C.G. Holladay, W.R. Barchet, H.P. Foote, W.F. Sandusky. 1986. Wind Energy Resource Atlas of the United States. Richland, Washington: Pacific Northwest Laboratory. Prepared for the U.S. Department of Energy (DOE). May 5, 2012. < http://rredc.nrel.gov/wind/pubs/atlas>.

English Heritage. 2005. Wind Energy and the Historic Environment. March 25, 2012. <http://www.english-heritage.org.uk/content/publications/docs/windenergyfinal.pdf>.

Enser, R.W. 1992. The atlas of breeding birds in Rhode Island. Rhode Island Department of Environmental Management.:206. Erba, G. 2012. Shedding light on photosensitivity, one of epilepsy's most complex conditions. May 1, 2012. <http://www.epilepsyfoundation.org/aboutepilepsy/seizures/photosensitivity/gerba.cfm>.

Erickson, W.P., Johnson, G.D., Strickland, M.D., Young, D.P. Jr., Sernke, K.J. and Good R.E. 2001. Avian collisions with wind turbines: a summary of existing studies and comparison to other sources of avian collision mortality in the United States. A report for the National Wind Coordinating Committee:67.

Erickson, W.P., Johnson, G.D. and Young, D.P. Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis collisions. USDA Forest Service general technical report PSW-GTR-191:14.

Faulkner, Tim. (2012, October 22). Two R.I. turbine projects could soon be spinning. *eco RI News*. Available online at: http://www.ecori.org/front-page-journal/2012/10/22/two-ri-turbine-projects-could-soon-be-spinning.html. Last accessed October 24, 2012.

Fiedler, J.K., Henry, T.H., Tankersley, R.D., and Nicholson, C.P. 2007. Results of bat and bird mortality monitoring at the expanded buffalo mountain windfarm, 2005. Report for the Tennessee Valley Authority: 42.

Gardner Appraisal Group Inc. (Derry T. Gardner). 2009. Impact of Wind Turbines on Market Value of Texas Rural Land. Prepared for the South Texas Plains Agriculture Wind & Wildlife Conference February 13, 2009 American Wind Power Center & Museum, Lubbock, Texas. Available online at: http://docs.wind-watch.org/gardner_wind-property-values_2_13_09.pdf. Last accessed October 14, 2012.

General Electric Ice Shedding and Ice Throw – Risk and Mitigation. David Wahl. GE Energy Greenville, SC. 2006. <http://www.gepower.com/prod_serv/products/tech_docs/en/downloads/ger4262.pdf>.

Gjestland, T. 2008. Background Noise Levels in Europe, European Aviation. Safety Agency Report SINTEF A6631.

Grilli, A., Malcolm Spaulding, Christopher Damon, Christopher O'Reilly, and Gopu Potty. 2012. Wind Resource Assessment and Siting of Wind Energy Facilities in Rhode Island. Prepared for the Rhode Island Renewable Energy Siting Partnership. See Volume II.

Grover, Stephen. 2002. Economic Impacts of Wind Power in Kittitas County. A Report for the Phoenix Economic Development Group by ECONorthwest. 20pp. Available online at: http://www.oregon.gov/energy/renew/wind/owwg/docs/economicdevelopmentkittitaswind.pdf. Last accessed October 15, 2012.

Haas, M. (2012, January 13). Putting renewable energy in right place. *eco RI News*. Available online at: http://www.ecori.org/renewable-energy/?currentPage=3. Last accessed October 20, 2012.

Haughton, J., Giuffre, D., Barrett, J. and Tuerck, D. G. (2004) An Economic Analysis of a Wind Farm in Nantucket Sound. Beacon Hill Institute at Suffolk University, Boston, MA. May, 2004. 83 pages. Available online at: http://www.beaconhill.org/BHIStudies/Windmills2004/WindFarmArmyCorps.pdf. Last accessed October 14, 3012.

Haviaropolous. *Environmental Impacts of Wind Farms: Myth and Reality*. Center for Renewable Energy Sources, Greece. 2011.

Heintzelman, Martin D. and Carrie M. Tuttle. In press. Values in the Wind: A Hedonic Analysis of Wind Power Facilities. *Land Economics*.

Heritage Council of New South Wales. 2003. Wind Farms & Heritage. March 25, 2012. Available online at: <http://www.heritage.nsw.gov.au/docs/windfarms2003.pdf>.

Hinman, Jennifer. 2010. Wind Farm Proximity and Property Values: A Pooled Hedonic Regression Analysis of Property Values in Central Illinois. Submitted on partial fulfillment of the requirements for the degree of Master of Science in Applied Economics, Illinois State University. May 3, 2012. <http://friendsofwind.ca/wp-content/uploads/2011/07/USA-2010-Hinman-Wind-Farm-Proximity-and-Property-Values.pdf>.

Hoen, B., Wiser, R., Cappers, P., Thayer, M. and Sethi, G. 2009. The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis. Prepared for the U.S. Department of Energy.

Hoen, B., Wiser, R., Cappers, P., Thayer, M. and Sethi, G. (2011) Wind energy facilities and residential properties: the effect of proximity and view on sales prices. *Journal of Real Estate Research*. 33(3): 279-316.

Hoen, Ben. 2012. "Research Investigating Wind Facility Effects On Nearby Property Values." PowerPoint lecture presented at RESP Property Values Workshop, URI Coastal Institute, Narragansett, on September 20, 2012.

Hoen, Ben. 2006. Impacts of Windmill Visibility on Property Values in Madison County, New York. Project Report Submitted to the Faculty of the Bard Center for Environmental Policy in partial fulfillment of the requirements for the degree of Master of Science in Environmental Policy. Bard College Center for Environmental Policy. May 3, 2012. <www.nhsec.nh.gov/2008-04/documents/app_appendix_30b.pdf>.

Hoover, S.L. and Morrison, M.L. 2005. Behavior of red-tailed hawks in a wind turbine development. Journal of Wildlife Management 69: 150-159.

Horn, J.W., Arnett, E.B. and Kunz, T.H. 2008. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72: 123-132.

Howe, R.W., Evans W. and Wolf A.T. 2002. Effects of wind turbines on birds and bats in Northeastern Wisconsin. Report for Wisconsin Public Service Corporation and Madison Gas and Electric Company:112.

Icing and the Wind Resource. Jeffery M. Freedman. AWS Truewind LLC. October 2009.

Icing and the Wind Resource. Jeffery M. Freedman. AWS Truewind LLC. October 2007.

Insignia Environmental. 2009. 2008/2009 Annual report for the Buena Vista avian and bat monitoring project. Report prepared for the Contra Costa County California:95.

Interference of Wind Turbines with Wide Area Communications. Massachusetts Technology Collaborative. June 25, 2006.

Johnson, G.D., Erickson, W.P., Strickland, M.D. and Shepherd, M.F. 2002. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30: 879-887.

Jones, A. and P. Vickery. 1997. Conserving grassland birds. Massachusetts Audubon Society, 208 So. Great Rd., Lincoln, MA 01773. Jan 19 2012. <http://www.massaudubon.org/Birds_and_Birding/grassland/>.

Kerns, J., Koford, R.R., Nicholson, C.P., O'Connell, T.J., Piorkowski, M.D., Tankersley, R.D. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management, 72: 61-78. Doi:10.2193/2007-221.

Kielisch, K. (2009) Wind Turbine Impact Study: Dodge and Fond Du Lac Counties, WI. Appraisal Group One. Prepared for Calumet County Citizens for Responsible Energy (CCCRE), Calumet County, WI. September 9, 2009. 73 pages. Available online at: http://docs.wind-watch.org/AGO-WIND-TURBINE-IMPACT-STUDY.pdf. Last accessed October 15, 2012.

Kingsley, A. and Whittam, B. 2005. Wind turbines and birds. A background review for environmental assessment. Report for Environment Canada: 81.

Khatri, M. (2004) RICS Wind Farm Research: Impact of Wind Farms on the Value of Residential Property and Agricultural Land. Prepared for Royal Institute of Chartered Surveyors, London, UK. November 3, 2004. 11 pages. Available online at: http://www.acousticecology.org/wind/winddocs/property/RICS_UK%20property%20values%20study.pdf. Last accessed October 15, 2012.

Kunz, T.H., Arnett, E.B., Cooper, B.M., Erickson, W.P., Larkin, R.P., Mabee, T., Morrison, M.L., Strickland, M.D. and Szewczak, J.M. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management 71: 2449-2486.

Kuvlesky, W.P., Leonard, A.B., Morrison, M.L., Boydston, K.K., Ballard, B.M. and Bryant, F.C.2007. Wind energy development and wildlife conservation: challenges and opportunities. Journal of Wildlife Management 71: 2487-2498.

Laposa, Steven P. and Andrew Mueller. 2010. Wind Farm Announcements and Rural Home Prices: Maxwell Ranch and Rural Northern Colorado. *The Journal of Sustainable Real Estate* **2** (1): 383-402. Available online at: http://www.costar.com/uploadedFiles/JOSRE/JournalPdfs/17.383_402.pdf. Last accessed October 24, 2012.

LeBlanc, M.P. 2007. Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario. Prepared for the Canadian Wind Energy Association. May 1, 2012. <http://www.canwea.ca/images/uploads/File/GH-RiskAssessment-38079or01a%281%29.pdf >.

Leddy, K.L., Higgins, K.F. and Naugle, D.E. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin 111: 100-104.

Lindley, D. 1994. The Future for Wind Energy Development in the UK – Prospects and Problems. *Renewable Energy* 5(1-4): 44-57.

Lothian, Andrew. 2006. Visual Impact Assessment of Wind Farms in South Australia. Presented at: New Zealand Association for Impact Assessment Conference, Dunedin, New Zealand, November 30, 2006.

Mabee, T.J., Plissner, J.H., Cooper, B.A. 2005. A radar and visual study of nocturnal bird and bat migration at the proposed Flat Rock Wind Power Project, New York, Fall 2004 Report to the Atlantic Renewable Energy Corporation:38.

Macaulay Land Research Institute. Visualisation Impact Assessment. Updated 2010. Available at: http://www.macaulay.ac.uk/ccw/task-three/via.html

Macaulay Land Research Institute. Visualisation Tools. 2010. <http://www.macaulay.ac.uk/ccw/task-three/vtools.html>.

MA DEP (Massachusetts Department of Environmental Protection) and MA DPH (Massachusetts Department of Public Health). 2012. Wind Turbine Health Impact Study: Report of Independent Expert Panel. January 2012. <http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf>.

Madsen, J. and Boertmann, D. 2008. Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. Landscape Ecology 23: 1007-1011.

Magnusson, Matthew and Ross Gittell. 2012. Impact of the Lempster Wind Power Project on Local Residential Property Values. Whittemore School of Business & Economics, University of New Hampshire, Durham, NH. 28 pp. Available online at: http://windworksvermont.org/uploads/14B_lempster_property_value_impacts_final.pdf. Last accessed October 15, 2012.

Masser, Paul. 2006. Environmental impact assessment of wind farms: cultural heritage and the problem of 'setting'. *The Archaeologist* 60: 12-13.

McCann, Michael. 2010. Report to Mike McLaughlin, Chairman Adams County Board Quincy, IL. McCann Appraisal, Chicago, IL. 82 pp. Available online at: http://www.co.champaign.il.us/countybd/zba/111006handouts3.pdf. Last accessed October 15, 2012.

McCann, Michael. 2012. Zoning Evaluation & Property Value Impact Study of Proposed Wind Turbine: Madaket Landfill Nantucket, Massachusetts. McCann Appraisal, Chicago IL. Prepared for Common Sense Nantucket. 43 pp. Available online at: http://docs.wind-watch.org/McCann_Jan_31_2012_ACK_zoning_evaluation_and_value_impact_study_FINAL-1.pdf. Last accessed October 15, 2012.

Merrill, J. and Knorr, K. 2012. Wind Resource Assessment Technical Report. Prepared for the Rhode Island Renewable Energy Siting Partnership. May, 2012. See Volume II.

Minnesota Department of Health. 2009. Public Health Impacts of Wind Turbines. May 1, 2012. <http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf>.

Møller H. and C. S. Pedersen, "Low-frequency noise from large wind turbines," J. Acoust. Soc. Am. 129 (6). June 2011

Morgan, C., Bossanyi, E., and Seifert, H. 1998. Assessment of safety risks arising from wind turbine icing. Proceedings of the International Conference, Wind Energy Production in ColdClimate, BOREAS IV, Hetta, Finland, Finnish Meteorological Institute. <http://www.renewwisconsin.org/wind/ToolboxFact%20Sheets/Assessment%20of%20risk%20due%20to%20ice.pdf>.

MORI Scotland. 2002. Tourist Attitudes towards Wind Farms. Research Study Conducted for Scottish Renewables Forum & the British Wind Energy Association.

Munksgaard, Jesper and Anders Larsen. 1995. Socio-economic assessment of wind power – lessons from Denmark. *Energy Policy* 26(2): 85-93. Available online at: http://www.apere.org/manager/docnum/doc/doc1244_DK.fiche21.pdf (last accessed October 1, 2012).

NATHPO. 2009. Narragansett Indian Tribe. 2012. <http://www.narragansett-tribe.org/directory.html>.

National Academy of Sciences 2007. Environmental Impacts of Wind Energy Projects, National Academy of Science <http://books.nap.edu/openbook.php?record_id=11935&page=160>.

National Research Council 2007. Environmental Impacts of Wind-Energy Projects. The National Academies Press, Washington, D.C., USA.: 278.

NCDC. 2008. Storm event database. National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center, U.S. Department of Commerce. <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms>.

Newton, I. 1998. Population limitation in birds. Academic Press, San Diego, California. M. E. Nilsson. 2007. Soundscape quality in Urban open areas, INTER-NOISE 2007 28-31 AUGUST 2007, ISTANBUL, TURKEY.

Nicholls, B. and Racey, P.A. 2007. Bats avoid radar installations: Could electromagnetic fields deter bats from colliding with wind turbines? PLoS ONE 2: e297. doi:10.1371/journal.pone.0000297.

NOAA (National Oceanic and Atmospheric Administration) 2008. Cloudiness – Mean Number of Days. May 1, 2012. <http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/cldy.html>.

NWCC (National Wind Coordinating Committee). 2002. Permitting of Wind Energy Facilities: A Handbook.

NYSDEC (New York State Department of Environmental Conservation). 2000. Assessing and Mitigating Visual Impacts.

NYSERDA (New York State Energy Research and Development Authority). 2009. New York State Wind Energy Toolkit.

Ofcom 2009. Tall Structures and their impact on Broadcast and other Wireless Services. Ofcom. April 26, 2009. <http://licensing.ofcom.org.uk/binaries/spectrum/fixed-terrestrial-links/wind-farms/tall_structures.pdf>.

Ohio Department of Health. 2008. Summary Report. Literature Research on the Potential Health Impacts Associated with Wind to Energy Turbine Operations. May 1, 2012. <http://www.odh.ohio.gov/~/media/ODH/ASSETS/Files/eh/health%20assessment%20section/windturbinehealthimpactsummaryreport.ashx >.

Olszewski, Donna and Tony Olszewski. 2012. Presentation at RESP Stakeholder Meeting, University of Rhode Island, Narragansett, RI on January 12, 2012.

Ontario Chief Medical Officer of Health. 2010. The Potential Health Impacts of Wind Turbines. May 1, 2012.<http://www.health.gov.on.ca/en/public/publications/ministry_reports/wind_turbine/wind_turbine.pdf>.

Orloff, S.G. and Flannery, A. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas 1989 - 1991. Report to the California Energy Commission: 199.

Osborn, R.G., Dieter, C.D., Higgins, K.F. and Usgaard, R.E. 1998. Bird flight characteristics nearwind turbines in Minnesota. American Midland Naturalist 139: 29-38.

Paton P., Sarah Butler and Corrie Heinz. 2012. THE EFFECTS OF TERRESTRIAL WIND FARMS ON BIRDS AND BATS: LITERATURE REVIEW FOR RHODE ISLAND'S RENEWABLE ENERGY SITING PARTNERSHIP PROJECT. See Volume II.

Pearce-Higgings, J.W., Stephen, L., Langston, R.H.W., Bainbridge, I.P. and Bullamn R. 2009. The distribution of breeding birds around upland wind farms. Journal of Applied Ecology 46: 1323-1331.

Pedersen and Waye 2004. Perception and annoyance due to wind turbine noise- a dose response relationship. *Journal of Acoustical Society of America* 116: 3460–3470.

Pedersen, E., LR-M. Hallberg, and K.P. Waye. 2007. Living in the vicinity of wind turbines – a grounded theory study. *Qualitative Research in Psychology* 4(1-2): 49-63.

Phadke, Roopali, Christie Manning, Asa Diebolt, and Matt Kazinka. 2009. Wind Energy and Scenic Considerations in Wyoming: Workshop Report.

Poletti, P. 2007. A Real Estate Study of the Proposed White Oak Wind Energy Center, Mclean & Woodford Counties, Illinois. Polleti and Associates. Prepared for Invenergy Wind LLC, Chicago, IL. January, 2007. 63 pages. Available online at: http://amherstislandwindinfo.com/aiw-docs/propertyvaluestudy.pdf. Last accessed October 15, 2012.

Poletti, P. 2011. Property Value Guarantees & Decommissioning Costs. PowerPoint lecture presented at the Siting, Zoning & Taxing of Wind Farms in Illinois Conference 2011, on February 9, 2011.

Potty, G. and Miller, J. 2012a. Acoustics Effects of Wind Farms: A Review. Prepared for the Rhode Island Renewable Energy Siting Partnership. See Volume II.

Potty, G. and Miller, J. 2012b. Wind Turbine Shadow Flicker and Signal Interference Effects. Prepared for the Rhode Island Renewable Energy Siting Partnership. See Volume II.

Radermakers, L. and H. Braam, 2005. Analysis of risk-involved incidents of wind turbines. In Guide for risk- based zoning of wind turbines. Energy Research Center of the Netherlands. <http://www.energy.ca.gov/2005publications/CEC-500-2005-184/CEC-500-2005-184.PDF>.

Raftery, Miriam. 2012. Tribes implore President Obama to stop Ocotillo Express wind project, save cultural resource sites, March 23, 2012. *East County Magazine*. March 26, 2012. <http://eastcountymagazine.org/node/9104>.

RERL (Renewable Energy Research Lab) 2006. Wind Turbine Noise, Infrasound, and Noise Perception. <http://www.windpoweringamerica.gov/pdfs/workshops/mwwg_turbine_noise.pdf>.

RERL. 2002, amended 2006. Wind Turbine Acoustic Noise: A white paper. *University of Massachusetts at Amherst*.

Reynolds, D.S. 2006. Monitoring the potential impact of a wind development site on bats in the Northeast. Journal of Wildlife Management 70: 1219-1227.

RHP&HC 2012 (Rhode Island Historical Preservation and Heritage Commission)

Roberts, Mark and Jennifer Roberts. 2010. Evaluation of the Scientific Literature on the Health Effects Associated with Wind Turbines and Low Frequency Sound. Wisconsin Public Service Commission. May 1, 2012. <http://www.maine.gov/dhhs/boh/documents/Wind-Turbine-Wisconsin-Assessment.pdf>.

Rogers, J. , Slegers N. and M. Costello, 2011. A method for defining wind turbine setback standards. *Wind Energy*.

Saidur, R., Rahim, N.A., Islam, M.R. and Solangi, K.H. 2011. Environmental inpact of wind energy. Renewable and sustainable energy reviews 15: 2423-2430.

Salt, AN and James A. Kaltenbach. Infrasound From Wind Turbines Could Affect Humans. *Bulletin of Science Technology & Society* 2011; 31: 296-302. http://bst.sagepub.com/content/31/4/296

Salt, AN and Jeffery T. Lichtenhan. Responses of the Inner Ear to Infrasound. *Fourth International Meeting on Wind Turbine Noise, Rome*. April 2011.

Salt, AN, and Hullar TE. Responses of the ear to low frequency sounds, infrasound and wind turbines. *Hearing Research* 2010; Vol. 268 September 2010: 12-21.

Schlossberg, S. and D. I. King. 2007. Ecology and management of scrub-shrub birds in NewEngland: a comprehensive review. USDA Natural Resources Conservation Service, Amherst, MA. <ftp://ftpfc.sc.egov.usda.gov/NHQ/nri/ceap/schlossbergkingreport.pdf>.

Scottish Natural Heritage. 2005. Guidance: Cumulative Effects of Windfarms.

Seifert et al 2003. *Risk Analysis of Ice Throw From Wind Turbines.* Henry Seifert, Annette Westerhellweg, and Jürgen Kröning of DEWI, 2003. <http://web1.msue.msu.edu/cdnr/icethrowseifertb.pdf>.

Sibley, D. A. 2003. The Sibley field guide to birds of eastern North America. A. Knopf Press, New York.

Sillett, T. S. and R. T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296-308.

Sims, S. and P. Dent. 2007a. Property stigma: wind farms are just the latest fashion. *Journal of Property Investment & Finance.* 25(6): 626-651.

Sims, S. and P. Dent. 2007b. What is the impact of wind farms on house prices? London: RICS; 2007 March. Findings in Built and Rural Environments (FiBRE) series report sponsored by the Royal Institute of Chartered Surveyors. Available online at: http://www.st-andrews.ac.uk/media/RICS%20Property%20report.pdf. Last accessed October 20, 2012.

Sims, S., Dent, P. and Oskrochi, G. R. 2008. Modeling the impact of wind farms on house prices in the UK. *International Journal of Strategic Property Management* 12(4): 251-269.

S. J. Baverstock, R. L. Pocock and K. Attenborough. 1991."Development of Area-Based Methods for Predicting Ambient Noise." Applied Acoustics, 33: 303-312.

Smallwood, K.S. and Karas, B. 2009. Avian and bat fatality rates at old-generation and repowered wind turbines in California. Journal of Wildlife Management 73: 1062-1071.

Smallwood, K.S. and Thelander, C.G. 2005. Bird mortality at the Altamont Pass Wind Resource Area March 1998-September 2001. Report for the National Renewable Energy Laboratory:411.

Smith, S.B., K.H. McPherson, J. Backer, B.J. Pierce, D. Podlesak, S.R. McWilliams. 2007. Fruit quality and consumption by songbirds during autumn migration. Wilson Journal of Ornithology 119:419-428.

Sterzinger, George, Fredric Beck, Damian Kostiuk. 2003. The Effect of Wind Development on Local Property Values. Washington, DC: Renewable Energy Policy Project. May 3, 2012. <http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf>.

Strickland, D., Arnett, E., Erickson, W., Johnson D., Johnson, G., Morrison, M., Shaffer, J., and Warren-Hicks, W. 2011. Comprehensive guide to studying wind energy/wildlife interactions. Report prepared for the National Wind Coordinating Collaborative:289.

Sunak, Yasin and Reinhard Madlener. 2012. The Impact of Wind Farms on Property Values: A Geographically Weighted Hedonic Pricing Model. FCN Working Paper No. 3/2012. Institute for Future Energy Consumer Needs and Behavior, School of Business and Economics / E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany. 40 pp. Available online at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2114216. Last accessed October 15, 2012.

Sustainable Development Commission 2005. Wind Power in the UK. Sustainable Development Commission. May 2005. < http://www.sd-commission.org.uk/publications/downloads/Wind_Energy-NovRev2005.pdf>.

Tammelin, B. et al.. 2001. Wind Energy in Cold Climate, Final Report FINNISH METEOROLOGICAL INSTITUTE, JOR3-CT95-0014 <http://cordis.europa.eu/documents/documentlibrary/47698271EN6.pdf>.

Thayer, R.L. and H. Hansen. 1988. Wind on the land. *Landscape Architecture* 78(2):68-73.

Thelander, C.G., Smallwood, K.S. and Rugge, L. 2003. Bird risk behaviors and fatalities at the Altamont Pass Wind Resource Area. National Renewable Energy Laboratory subcontractor report:92.

Toensing, Gail Courey. 2011. Aquinnah Wampanoag sues feds over Cape Wind, July 14, 2011. *Indian Country Today Media Network*. >. March 26, 2012. <http://indiancountrytodaymedianetwork.com/2011/07/14/aquinnah-wampanoag-sues-feds-over-cape-wind-42712

UK Shadow Flicker Evidence Base, Department of Energy and Climate Change. 2011. Update of UK Shadow Flicker Evidence Base, Final Report, Prepared by Parsons Brinckerhoff for Department of Energy and Climate Change, London, 2011. <http://www.decc.gov.uk/>.

University of Massachusetts at Amherst Renewable Energy Research Laboratory. 2000. *Wind Energy: Cold Weather Issues*. Antoine Lacroix. University of Massachusetts at Amherst Renewable Energy Research Laboratory. June 2000.

USDOE. 2010. Impact of Wind Power Projects on Residential Property Values: A NEWEEP Webinar, Annotated Bibliography. Available online at:

http://www.windpoweringamerica.gov/filter_detail.asp?itemid=2610&pga=ne_forum. Last accessed October 1, 2012.

US Fish and Wildlife Service. 2011. U.S. Fish and Wildlife Service Draft Land-Based Wind Energy Guidelines. USFWS Report:83.

US FWS (Fish and Wildlife Service). 2012. Barrier Effect. May 6, 2012. <http://www.fws.gov/windenergy/docs/Barrier_Effect.pdf>.

Vermont Department of Forests, Parks, and Recreation. 2004. Land Use and Recreational Impacts of Wind Energy: Cold Weather Issues. Antoine Lacroix. University of Massachusetts at AmherstRenewable Energy Research Laboratory. June 2000.

Vissering, J., Margolis, A., Sinclair, M. 2011. A VISUAL IMPACT ASSESSMENT PROCESS FOR WIND ENERGY PROJECTS. *Clean Energy States Alliance State Clean Energy Program Guide.* May 2011.

Wind Energy Projects. March 26, 2012. <http://www.vtfpr.org/wind/workingpapers/recreational_impact.pdf>.

Zahodiakin, Phil. 2012. Turbine sparks veiled threat from state. *The Jamestown Press.* May 2,2012.<http://www.jamestownpress.com/news/2012-01-19/Front_Page/Turbine_sparks_veiled_threat_from_state.html

RENEWABLE ENERGY SITING PARTNERSHIP

CHAPTER 2. LANDFILL SOLAR

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

According to the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER), approximately 490,000 sites and 15 million acres of contaminated properties exist nationwide (EPA 2011(a)). Meanwhile, growth in electricity demand is expected to lead to a nearly 30% increase in production (Conti et al. 2008; Solfocus 2008). Against this backdrop, the EPA launched the RE-Powering America's Land Initiative (EPA 2012(c)), which promotes renewable energy development as a means of revitalizing real estate formerly occupied by dumps, landfills, and other brownfields.

"Repowering" these properties promises a dual benefit: an increase in power production from renewable sources which might otherwise require development of green spaces, but in this case adaptively reuses fallow land. Rhode Island is well-positioned to realize this potential synergy. As the second most densely-populated state in the nation (Wikipedia 2012), Rhode Island faces geographic limitations on the amount of space available for indigenous energy production. If the Ocean State wishes to increase its domestic renewable power supply, strategic siting of electricity generation facilities is paramount.

The following study examines what, if any, opportunities exist to capture solar resources on contaminated properties, specifically landfills, in the Ocean State. The analysis addresses the twin questions of whether Rhode Island landfills can support large, utility-scale photovoltaic (PV) solar power facilities and what barriers stand in the way of realizing these opportunities. This chapter first discusses technical, environmental, and regulatory considerations related to the general siting of solar energy facilities on landfills. It then presents a state-specific, screening methodology developed by the RESP to identify solar energy opportunities on Rhode Island landfills.

Objectives

The purpose of the RESP landfill solar analysis was to assess available energy resources and development constraints for utility-scale solar arrays (defined as producing 1 MW or more) on closed landfill sites. There are three main objectives of this analysis:

- Develop landfill solar energy site screening tools.
- Using these tools, assess how many megawatts of photovoltaic solar energy could potentially be generated on suitable land on closed Rhode Island landfills.
- Identify which landfills are suitable for generating at least 1 MW each of solar power.

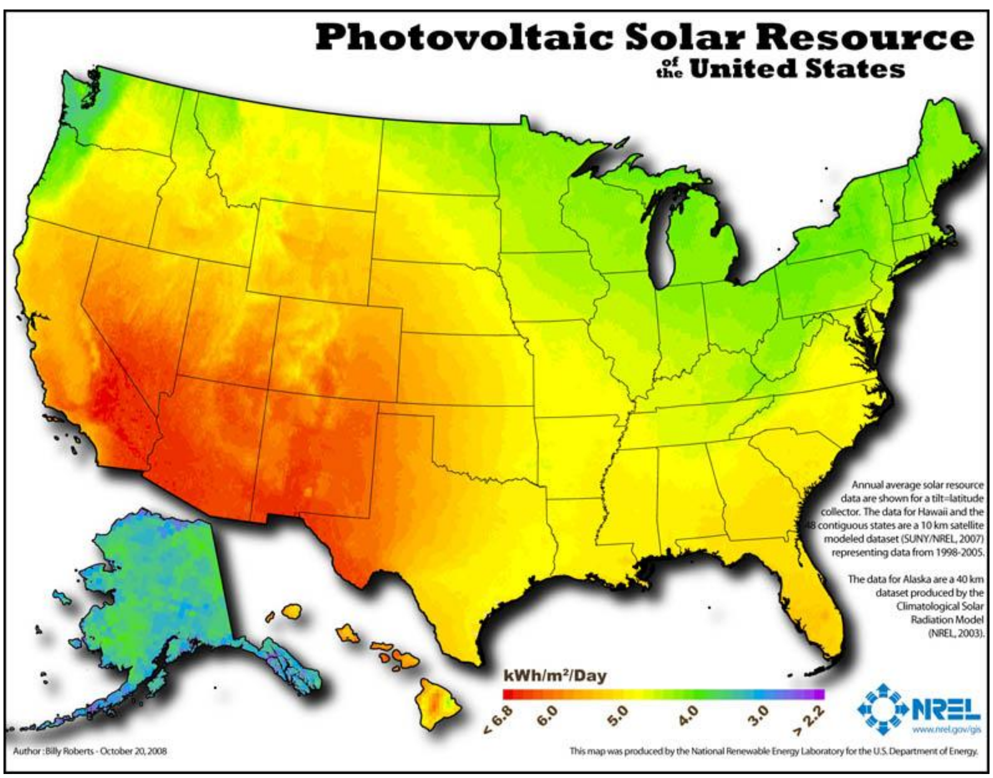
2. TECHNICAL SITING CONSIDERATIONS

The technical viability of developing solar electricity generation on landfills depends on four main ingredients: the available solar resource at the site, physical and biological characteristics of the location, photovoltaic (PV) system design specifications, and site characteristics of the landfill.

2.1 Solar Resource

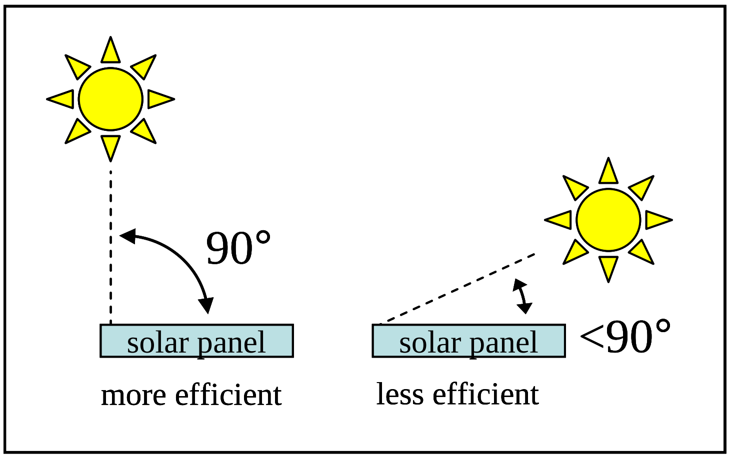
The available solar resource at a given location is measured in terms of irradiance, or power per unit area (watts/m2). Solar radiation absorbed at the earth's surface varies both geographically and over time, due to a diversity of factors including topography, weather, time of day, season, latitude, and the changing distance and orientation between the earth and sun.

There are two components of sunlight: diffuse and direct radiation. As sunlight passes through the earth's atmosphere, it is absorbed, scattered, and reflected by water vapor, clouds, dust, salt, pollutants, and smoke. The term 'diffuse irradiance' describes the component of solar radiation deflected by these atmospheric gases and suspended particles. Sunlight that passes through the atmosphere without being diffused is called direct normal, or 'beam', irradiance. During overcast days, diffuse irradiance accounts for a greater portion of the light. Solar PV panels utilize the energy in diffuse radiation less efficiently than they are able to utilize direct radiation.



Ch. 2 Figure 1. Map of solar availability in the United States (Roberts 2008).

Whereas *irradiance* refers to the rate at which power is delivered to a surface (watts/m^2), *insolation* describes the total amount of power delivered to that surface over an interval of time (watt-hours/m^2) (Sargosis Solar & Electric, no date). The amount of solar energy striking a surface is greatest when the surface directly faces the sun (i.e., at a 90° angle) (Figure 2). As the angle between the sun's rays and the surface decreases (to less than a 90° angle), as occurs during afternoon hours, the amount of direct insolation also decreases. The earth's orbit around the sun has a similar effect on insolation: during summer months, the suns' rays hit the northern hemisphere more directly (closer to a 90° angle), resulting in a greater solar energy potential during that time of year. Lower latitudes receive a greater portion of their annual sunlight at angles closer to 90°.



Ch. 2 Figure 2. Solar angles.

2.2 Climatic and Physical Siting Factors

In addition to the raw solar resource available at a site, several other physical attributes of a site determine its suitability as a location for solar PV systems. These considerations include rainfall, wind loading, snow loading, hail impacts, and temperature effects.

2.2.1 Rainfall

Rainfall has both negative and positive impacts on solar PV systems. The amount of rainfall is related to cloud cover, which decreases direct solar irradiance. Conversely, rainfall helps to clean PV panels, which optimizes their efficiency. Average monthly rainfall at four locations throughout Rhode Island ranges from nearly 3 inches/month to over 5 inches/month (Weather Channel 2012). Rainfall in New England is sufficient to help mitigate the need for hand-cleaning of panels (Stafford et al. 2011).

2.2.2 Wind Loading

Wind loading is the amount of force exerted per unit area by wind on a surface. It affects both the stability of the panel mounts and the panels themselves. Panels that are mounted higher above ground to avoid shading from vegetation, or panels with higher tilt angles tend to be more exposed to winds, requiring stronger, heavier mounts to hold the modules in place (Stafford et al. 2011; MassDOER 2012). These heavier loads can place greater strain on landfill covers and side slopes. PV panels themselves are typically certified to withstand maximum mechanical loads of 50 lbs/ft2, which equates to wind speeds of approximately 105 mph, or speeds typical of a Category 2 hurricane (Sampson 2009; NHC 2012).

2.2.3 Snow Loading

Snow loading on the PV array depends on a multitude of factors. These include the water content of the snow, depth of snow, cloud cover (which prevents snow from melting), panel tilt (which, at steep angles, causes snow to slide off), and freeze-thaw cycles (which can cause ice to build up on the modules and prevent snow from sliding off) (Stafford et al. 2011; MassDOER 2012). Snow loading generally has a more significant effect on the mounting structure than on the panels themselves. Typically, permitting for a solar project will require that a structural principal engineer provide evidence that the supporting structure can handle a certain level of snow loads. Panels themselves are engineered to support maximum loads of 50 lbs/ft^2, which is approximately equivalent to a 10-inch thick ice layer. Ground-level snow loads in Rhode Island average between 30 and 40 lbs/ft^2, within the range withstood by most PV systems (ASCE, 2005). However, not all solar panel manufacturers cover snow damage in their warranties.

2.2.4 Hail Impacts

Hail impacts on the PV array may cause both physical and/or electrical damage. PV modules should be able to withstand such impacts in the event of falling hail (ASTM International 2012). ASTM International E1038-10 conducts hail impact tests on PV modules demonstrating the ability to withstand one inch hail balls at terminal velocity of 52 mph (ASTM International 2012).

2.2.4 Temperature Effects

Solar panels operate more efficiently at lower temperatures (SolFocus 2012). Panel manufacturers use standard conditions of 25°C (77°F) to establish published module efficiencies (Stafford et al. 2011). At higher temperatures, PV modules can have more than a 20% reduction in energy output relative to these published efficiencies (SolFocus 2008). Records from TF Green airport from 1949 to 2011 show maximum monthly temperatures above 77°F (standard conditions for PV panel testing) occurring during each month from March through November, with extreme highs reaching 100-104°F in July, August, and September (NCDC 2012). Average high temperatures during the summer are 78°F, 83°F, and 81°F for June, July, and August, respectively. These temperatures are within the typical PV operating conditions, indicating that average Rhode Island temperatures do not present problems for PV operations (Weather Channel

2012). However, on extreme temperature days, losses in panel efficiency may occur (SolFocus 2008).

2.2.5 Shading Obstructions

To optimize PV system output, shading of panels by trees, buildings, or other obstructions should be avoided. Baseline shading effects are typically determined based on conditions 90 minutes after sunrise and 90 minutes before sunset, as well as at noon on the winter solstice (December 21st), when the sun is at its lowest zenith of the year (MassDOER 2012). In the New England region, the setback ratio for shade-producing obstructions should be a minimum of 3:1. For example, a solar array should maintain a 150' buffer from a 50'-tall tree line in the easterly, southerly and westerly directions. Setback ratio in the northerly direction should be 1:1 to provide a fall zone for potentially unstable obstructions, such as trees, utility poles, etc. In addition to shade-producing obstructions, PV module efficiency is reduced if grasses or other vegetation reach above the height of the panel mount. Regular cutting of vegetation can alleviate this potential problem.

2.3 PV System

A variety of technologies exist to extract energy from the sun. The simplest application of solar power, called "passive" solar, uses building design principles as a means to collect, store, and distribute solar energy in the form of heat. More complex "active" solar systems can generate heat (solar thermal), or produce electricity (photovoltaics). The RESP solar landfill analysis focused exclusively on photovoltaic systems, which rely on receptor panels to convert sunlight to electricity. Several technologies exist within the general category of photovoltaic systems, each optimized for different objectives and varying conditions. The type of technology selected and the design specifications employed during installation are a third determinant, in addition to sunlight and landfill characteristics, of the technical viability of developing solar electricity generation on landfills.

2.3.1 Photovoltaic Technologies

Photovoltaic (PV) panels (also called modules) consist of multiple solar PV cells wired together in series. Typical PV arrays consist of one or more solar panels mounted together and are located most commonly on rooftops, carports, or the ground. Solar PV technologies generally fall into three categories: rigid flat plate collectors, concentrator systems, and flexible laminates (DoE 2011(c)). Each type of system has its own unique set of advantages and disadvantages. For example, PV efficiency, or the ratio of the sun's energy at the module surface to the electrical power generated by the PV panel (DoE 2011(b)), varies significantly according to system type. Price, application considerations, and maintenance requirements, among other factors, also vary by system type.

Rigid Flat Plate Collectors

The most common type of PV technology is the rigid flat plate collector, which generally use either silicon monocrystalline or polycrystalline cells to generate electricity from sunlight. Panels with monocrystalline cells are the most efficient modules available followed by those with polycrystalline cells. Both types are rigid and comparatively heavy and expensive. Rigid monocrystalline panels (Ch. 2 Figure 3) have approximately 23% efficiency under standard conditions (25°C/77°F and 1,000 watts/acre) and about 13 - 19% efficiency when used in 'real world' conditions (Mendelsohn et al. 2012; SolFocus 2008).

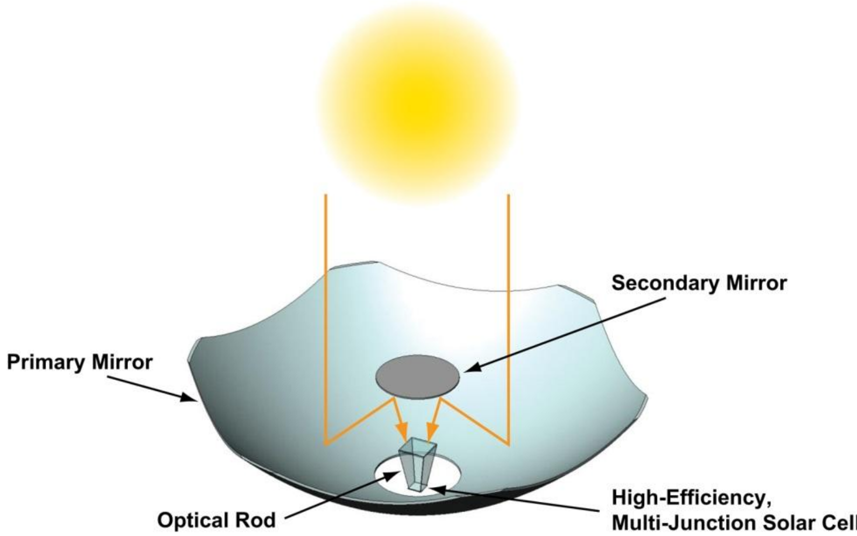
Ch. 2 Figure 3. Rigid Crystalline Photovoltaic Panels in a Fixed Tilt Array (PPL 2010).

Rigid flat plate collectors can be mounted statically or set up to dynamically track the sun. Sun-tracking modules (Ch. 2 Figure 4) automatically adjust the panel tilt to maintain a 90° angle with the sun's rays at all times as the sun's position in the sky changes. Single axis systems track east to west to maintain optimal angle with the sun throughout the day. Dual axis systems track in both the east-west plane and in the north-south plane to maintain optimal panel angle with the sun throughout the hours of the day and the seasons of the year. Because they are able to maintain a more direct angle to incoming sunlight, these systems have greater efficiencies than their fixed counterparts (DoE 2011(a)). However, there are trade-offs between these and statically mounted systems. Although sun-tracking systems generate more power, a portion of the power must supply the energy needs of the small tracking motor on each module. Additionally, single- and double-axis sun-tracking PV modules are more expensive both to purchase and to maintain. They also require greater space between panels (and consequently, greater total land area) so that their moving shadows do not interfere with adjacent panels (Sampson 2009). Finally, sun-tracking systems are heavier than statically mounted panels. This can be problematic in landfill applications, as it can promote waste settlement within the landfill and even puncture the protective landfill cap (Stafford et al. 2011). It is difficult to adequately support a tracking system due to limitations on minimal or no penetration depth for anchoring. Additionally, many tracking systems are not engineered for the snow and wind loads found in the New England region. Cost/benefit data in this region remains lacking. For these reasons, caution is needed when considering deployment of tracking systems on landfills.

Ch. 2 Figure 4. Mount and Racking for Dual Axis Tracking Rigid Crystalline PV Panel (Parish 2009).

Concentrating Photovoltaic (CPV) Panels

Concentrating photovoltaic systems use mirrors and lenses to refocus sunlight onto a centrally positioned photovoltaic receiver (Ch. 2 Figure 5 and Ch. 2 Figure 6). These systems track the sun to maximize the energy produced and operate at efficiencies of approximately 40% - 43.5% (Brown 2011; SolFocus 2012). These efficiencies, however, are based on CPV usage in optimum conditions, such as cloud-free areas like the American Southwest, rather than areas with higher levels of diffuse sunlight, such as Rhode Island (SolFocus 2008). Concentrating solar power systems are best suited for large-scale production plants with a capacity of at least 50 MW. Currently, installation of this type of solar energy system on landfill sites is not feasible, due to weight issues and acreage requirements (Sampson 2009; Tansel et al. 2010).



Ch. 2 Figure 5. CPV Cell (SolFocus 2008).

Ch. 2 Figure 6. Many CPV Cells in a CPV Panel (SolFocus 2012).

Flexible Panels

Flexible solar modules are also known as thin film laminates (Ch. 2 Figure 7). Currently, they are less efficient than rigid panels, with approximately 20% efficiency under standard conditions and 6 - 10% efficiency in the field (Stafford et al. 2011; SolFocus 2008). These panels are relatively new to the market, especially in landfill applications. As such, there are not many case studies to learn from. One system in Georgia uses approximately 10 acres to generate 1 MW of power (CES 2011(a)).

A major advantage of thin films over their rigid crystalline counterparts is that they can conform to changing ground conditions, which may develop in landfill applications as a result of differential settlement of the waste beneath the PV array (see arrow in Ch. 2 Figure 7). Additionally, the lower profile of flexible solar modules allows more space for waste in the landfill. Thin film laminates may also reduce the cost and maintenance requirements associated with landfill caps by substituting for traditional capping material (i.e. geomembranes, soil, and vegetation) and obviating the need for grass seeding, mowing, and irrigation. Water runs off the surface of PV laminates, which reduces concerns of rainwater infiltration into the landfill. This safeguards the cap and reduces the frequency with which sediment must be removed from nearby retention ponds (CES 2011(b)). Due to their light weight, thin film laminates are recommended for use on landfill side slopes where they pose less risk of slope destabilization than heavier, rigid panels (Stafford et al. 2011) (see Section 2.4.3 for more information). Thin film, however, can also be deployed on rigid panels and is a good solution where acreage is not a limiting factor. Installed in the same manner as other rigid panels, this application is more advantageous than a flexible application in cases where a landfill has vegetative cover and is subject to soiling from snow. A thin film array will capture more diffuse light at the beginning and end of the day and outperform a rigid panel array of equivalent nameplate capacity, all else being equal.

Ch. 2 Figure 7. Flexible Solar PV panels with Arrow Indicating Slope Change (Adapted from CES 2011(a)).

2.3.2 Orientation and Tilt

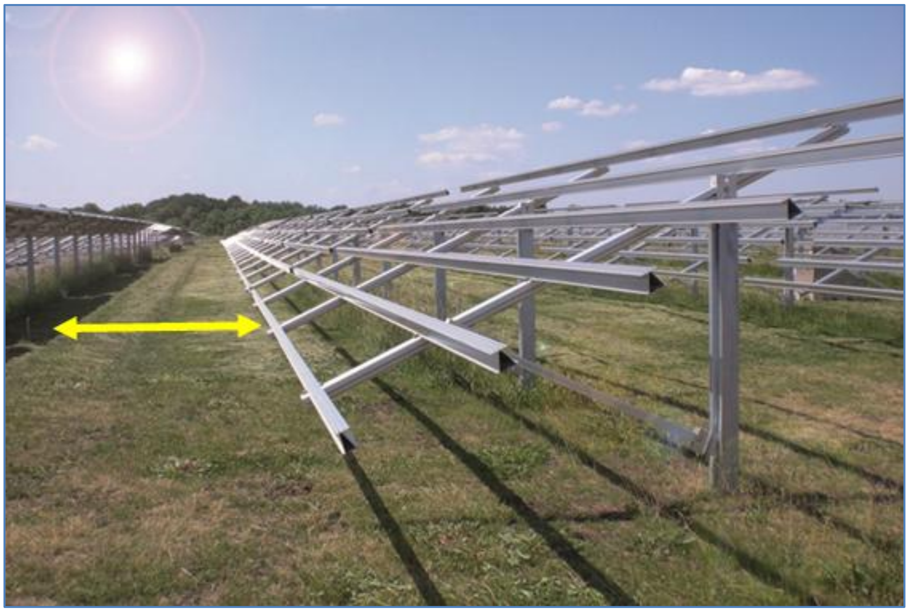
The orientation and tilt of PV panels must be configured to maximize the capture of solar energy. Optimal orientation for harvesting incident sunlight in the northern hemisphere is due south (i.e., “true”, not “magnetic,” south). The ideal tilt angle of PV modules varies according to time of year; in summer, when the sun appears higher in the sky, the ideal panel tilt angle is lower than in winter. At all times of year, PV panel efficiency can be maximized by placing modules as close as possible to a 90° angle relative to incoming solar rays. Generally, tilt angle is calculated as the site's latitude ±15°, although specific adjustments need to be made for each site (Stafford et al. 2011; Tansel et al. 2010).

2.3.3 Balance of System Equipment

PV panels require a variety of ancillary equipment, sometimes referred to as balance of system (BOS) equipment. This equipment includes mounts/racks, ballast/footings/foundations, wiring, inverters, and transformers.

Racks hold the module in place and maintain the proper angle between the panel and the sun (Ch. 2 Figure 8). The footing or ballast helps resist wind loading and holds the rack or mount in place (MassDOER 2012). Solar arrays placed on landfills should not use foundations that penetrate the ground as this compromises the landfill cap, exposing the PV system to underlying waste and corrosive landfill gases, while introducing rainwater into the landfill which can cause contaminated leachate (Stafford et al. 2011). Panel support systems that do not penetrate the ground include shallow poured concrete pillars, pre-fabricated concrete, slab, and ballast frames (Sampson 2009). Slab foundations are not recommended for landfills as they are heavier and can cause settling of the landfill waste. Settling can cause cracking and destabilization of the PV panel arrays (Sampson 2009). Site-specific cost, weight, and strength considerations determine which of the foundation choices are most suitable. Frost heave (i.e. upward movement of soil resulting from water volume expansion during freezing) can occur in the upper few feet of the ground. This site-specific factor affects panels with foundations placed at or near ground level, causing permanent alteration of panel tilt, structural problems, and other negative impacts.

Electrical balance of system equipment includes the wiring, inverters, and transformers required for operation of the PV system and transmission of electricity produced to the grid. Solar arrays produce direct current (DC) power, which an inverter changes to alternating current (AC), the form of current used by the grid. Transformers increase or decrease the voltage of the AC power between the solar array and the grid.



Ch. 2 Figure 8. Rigid Panel PV Mounts with Row Spacing Indicated (Adapted from Prweb.com 2012).

2.3.4 Pressure on Landfill Cap

Excessive weight loads associated with the construction and maintenance of a PV system can compromise the performance of a landfill cap by leading to puncture of the cap, excessive settlement, side slope instability, and erosion (Sampson 2009; EPA and NREL no date). Loads may come from the PV structure itself, or from snow, wind, and seismic loads. In addition, construction and maintenance vehicles can temporarily increase loads on a landfill cap.

2.4 Landfill Site Suitability

Landfills, like other types of brownfield sites, are often considered attractive locations for siting renewable energy facilities. Many landfill sites are physically suited for solar development: Landfills generally contain open acreage with unobstructed access to sunlight. Landfill sites generally have few owners and can be adequately zoned for solar development. Critical infrastructure, such as electric distribution lines and roads, is often already in place or proximate. However, not all landfills meet these conditions. Furthermore, the primary purpose of all landfills is to keep disposed waste separated from the surrounding environment. Any secondary reuse of the property, such as recreation, or, in this case, solar power generation, should not jeopardize the landfill's primary purpose. Therefore, determining whether a landfill is compatible with solar development requires consideration of existing site conditions.

2.4.1 Current Use

The principal factor affecting the suitability of a landfill for solar energy development is the current use of the landfill. Many former landfills have been repurposed for other uses such as athletic fields, industrial and commercial areas, and composting facilities. For landfills currently occupied by some other type of passive or active use (e.g. recreation), the appropriate stakeholders must evaluate the relative merits of preserving the current use or redeveloping the site for solar electricity generation.

2.4.2 Location

Interconnection Access

Proximity of the landfill site to electrical grid infrastructure (three-phase distribution circuits) is paramount to ensuring that electricity produced by a landfill-based PV system can be supplied to the electrical distribution system. In Rhode Island, the electric distribution utility, National Grid, manages interconnection between distributed generation projects and the grid. Communication should be established with National Grid during the early stages of project planning to evaluate interconnection feasibility (Kennedy 2012. Personal communication). The electric load carrying capacity of the lines must be adequate to carry peak electricity loads generated by a PV array (e.g., greater than 1MW in the case of this study). According to the EPA and National Renewable Energy Lab (NREL), distances over ½ mile between a solar energy generation site and the nearest interconnection point tend to make a project unviable (EPA and NREL no date). However, the maximum feasible distance required for grid tie-in is highly dependent on the budgetary considerations of each individual project.

Vehicle Access

Vehicle access is another consideration affecting the suitability of a landfill for solar energy development. Roads providing access to the site must be able to withstand traffic from vehicles and machinery required for the installation, operation, and maintenance of the PV system. EPA and NREL recommend using one mile as a screening measure of whether building or grading of access roads may be cost prohibitive, however, this will vary by site and project economics (EPA and NREL no date).

2.4.3 Landfill Cap and Lining

Landfills receive a variety of waste materials, some of which may present a threat to the environment or human health. Landfill caps, a type of containment treatment/waste management practice, help manage this risk by forming a barrier between waste and the surrounding environment. Although cap technology does not directly reduce the amount, mobility, or toxicity of landfill waste, it mitigates and controls the migration of harmful materials at the site (Van Deuren et al. 2002). Properly designed and maintained landfill caps will continue functioning for tens or even hundreds of years. There are several key functions of a landfill cap (Van Deuren et al. 2002):

- Minimize exposure of the waste
- Prevent infiltration of water into wastes, thereby reducing contaminated leachate
- Contain waste

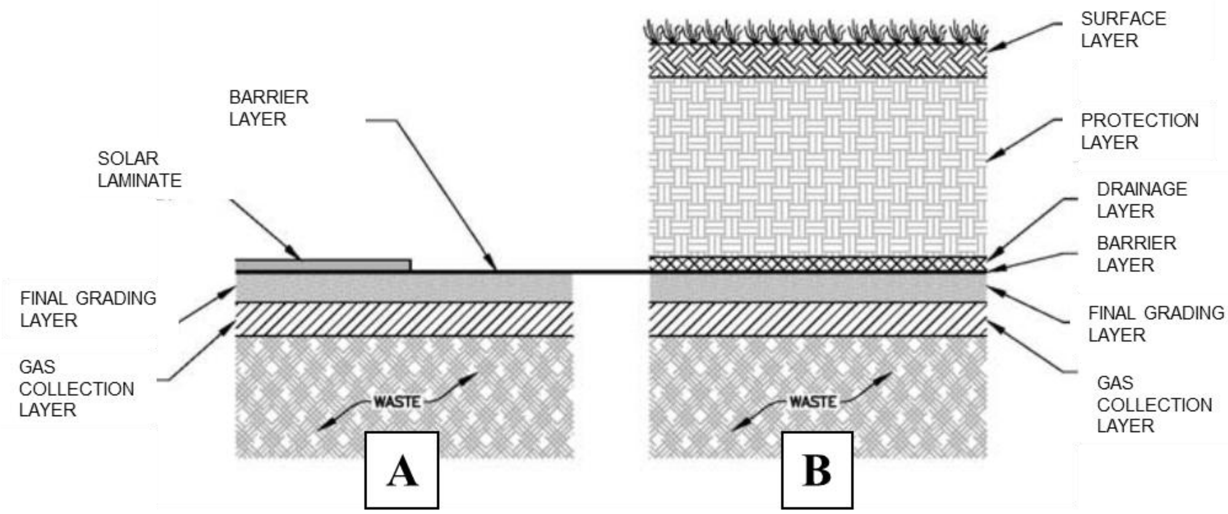
- Control gas emissions from underlying waste
- Create a land surface that can support vegetation and/or be used for other purposes

Traditional Covers

Choice of landfill cap design is determined by the environmental characteristics of a site, specific waste management needs, and cap regulations at the time of landfill closure. Typical modern engineered caps consist of several layers, including a gas collection, barrier, drainage, protection, and surface layer (Ch. 2 Figure 9). The gas collection layer is a geotextile or gravel layer which allows corrosive gases generated by waste decomposition to migrate out of the landfill. These landfill gases are generally about 45% methane, 55% carbon dioxide, and traces of other gases (Republic Services 2010). Methane is explosive and, in combination with hydrogen sulfide (H_2S) gas, produces nuisance odors (Stafford et al. 2011). As such, it is important to control release of these gases from a landfill. The grading layer is used to keep a steady, low-angled slope on the surface of the landfill to encourage water to run off gently. This is done to control erosion and to make sure that water does not pond on the landfill top deck. The barrier layer consists of a low-permeability compacted clay liner, geomembrane, or composites of both. This layer acts to prevent water from infiltrating into the waste below. The drainage layer comprises high-permeability materials such as granular soil and/or geotextiles. This layer acts to receive and carry away water percolating down from the surface. The protection layer and surface layer form a protective soil cover over the lower layers, and are often seeded with vegetation (Ch. 2 Table 1 and Ch. 2 Figure 9).

Ch. 2 Table 1. Configuration of Cover Systems (EPA 1993).

Layer	*Primary Function*	*Usual Materials*	*General Considerations*
1. Surface Layer	Promotes vegetative growth (Most covers); Decrease erosion; Promote evapotranspiration.	Topsoil (humid site); Cobbles (arid Site); Geosynthetic erosion control systems	Usually required for control of water and/or wind erosion
2. Protection Layer	Protect underlying layers from intrusion and barrier layer from desiccation and freeze/thaw damage; Maintain stability; storage of water	Mixed soils; Cobbles	Usually required; May be combined with the protective layer into a single "cover soil" layer
3. Drainage Layer	Drain away infiltrating water to dissipate seepage forces	Sands; gravels; geotextiles; geonets; geocomposites	Optional; Necessary where excessive water passes through protection layer or seepage forces are excessive
4. Barrier Layer	Reduce further leaching of waste by minimizing infiltration of water into waste; Aid in directing gas to the emissions control system by reducing the amount leaving through the top of the cover	Compacted clay liners; Geomembranes; Geosynthetic clay liners; Composites	Usually required; May not be needed at extremely arid sites
5. Gas Collection Layer	Transmit gas to collection points for removal and/or cogeneration	Sand; geotextiles; geonets	Usually required if waste produces excessive quantities of gas



Ch. 2 Figure 9. A) Landfill Caps with Flexible PV Panels; B) Traditional Landfill Cap (Modified from Sampson 2009).

Solar Energy Covers

Composite technologies such as the Solar Energy Cover (SEC) integrate renewable energy production into the landfill cap system. Ch. 2 Figure 9 displays the design differences between a traditional landfill cap and the SEC system. In a traditional landfill cover, the drainage, protective, and surface layers provide ballasting and protection material over the geomembrane. In the SEC design, these layers are replaced by a solar laminate layer lying directly over the geomembrane, obviating the need for the additional ballasting and protective layers employed in the traditional cap design (Ch. 2 Figure 10).

The SEC provides a number of benefits over a traditional cap design. It mitigates problems such as erosion, slope failure, and saturated soil conditions by diverting water off the cap. Efficient channeling of rainwater off the cover also prevents ponding, which can result in pressure on the surface of the geomembrane. By eliminating the geocomposite and soil/vegetation layers found in a traditional landfill cap, the SEC makes the geomembrane easily accessible for inspections and maintenance. Forgoing these additional layers also helps lower the costs associated with the landfill cap. In fact, the economics of integrating solar power directly into the cap may help create an incentive for communities to pay for capping a landfill (CES 2011(c); RIRRC 2011).

Some of the drawbacks of SEC capping systems include the lower solar power generation capacity of the flexible modules, degradation of modules by oxygen and UV light, vulnerability to wind shear, higher stormwater peak flows as a result of increased impervious surface area, dangers to operations and maintenance workers resulting from the slippery plastic surface, and the risk that snow may cover up the solar cells because of fairly shallow slopes. Many of these issues can be mitigated. For instance, anti-oxidants and UV-stabilizers can be used to protect the plastic, anchor tie-downs can be used to keep the films in place, and walkways can be constructed to safeguard workers. On the positive side, the slippery surface of the films can enhance snow slide-off and the incorporated PV panels can act as heat sinks that help to melt snow (RIRRC, 2011). Because of the aforementioned considerations, SEC caps technologies are best suited for and most commonly used on landfill side slopes rather than on the landfill top deck (CES 2011(c); RIRRC 2011).

Ch. 2 Figure 10. Geomembrane Cap with Incorporated Solar Panels on Landfill Side Slopes in New York State (Barton and Loguidice, P.C. 2011).

2.4.4 Topography

Cap Top Deck Area & Slope

Flat areas directly exposed to sunlight, such as the landfill's top deck, are the best places to site rigid flat plate PV arrays. For a landfill cap deck to be appropriate for solar development, the EPA recommends a slope between 3 and 5 degrees (5 to 9% slope) to avoid shading, erosion, and infiltration problems (EPA and NREL no date). Steeper angles require more complex ballast mounting systems. Alternately, if financially feasible, the site can be mechanically graded to attain the required slope.

Cap Azimuth

Azimuth is a term indicating compass direction. In the northern hemisphere, the ideal azimuth for solar energy modules on sloped surfaces (such as the flanks of a landfill) in the northern hemisphere is 180°, or due south (true south, not magnetic south) (MassDOER 2012). Generally, it is optimal for solar modules to face within 15° of true south, but they can face anywhere from east/southeast through to nearly due west and still operate efficiently if the tilt of the array is matched to suit. For horizontal PV panels (such as flexible laminates on flat ground) azimuth is irrelevant (Stafford et al. 2011).

Landfill Side Slope Angle

PV panels can be placed on south-facing side slopes, however, many such slopes are too steep to maximize summertime solar collection. Side slope angle also affects the stability of the landfill and is key in determining the ability of the landfill to withstand the weight load of a solar array on its top deck (Sampson 2009). Additionally, side slope angle affects cap erosion by influencing the rate of stormwater runoff, and is an important input into a landfill's stormwater management plan. Due to the costliness of constructing heavy foundations associated with rigid panel systems on side slopes, flexible PV laminates are considered better suited to landfill side slopes. Laminates have the added benefit of reducing erosion on side slopes.

Vegetation Cover

Older landfills may be covered by brush or trees. Removal of vegetative growth can increase the amount of unobstructed sunlight reaching solar panels. Vegetation on the top deck may need periodic maintenance, such as mowing during the growing season. This consideration affects the packing factor (i.e., the density of individual panels in an array), as mowing equipment must be able to fit between panels. PV modules should be installed with their lower edge approximately 3 feet off the ground to minimize shading by vegetation (Stafford et al. 2011). The stormwater management plan for the landfill must be consulted to assure that the loss of vegetation on the cap due to panel foundations and shading does not negatively impact cap performance or result in increased stormwater runoff.

2.4.5 Settlement Factors

Decomposition of landfill waste causes a landfill's volume to decrease with time. As volume decreases, the landfill cap sinks downwards. This settlement can occur uniformly across a landfill or in localized areas (Sampson 2009). Uneven, differential settlement poses a risk to the structural integrity of the cover system and to any structures situated on the landfill surface (McAllen 2012. Personal communication). Settlement processes may affect both the physical structure and performance of a cap-mounted PV system. Differential settling can compromise system components including array piers, footings, and electrical wiring, and may disturb the integrity and orientation of the panels (Sampson 2009; EPA and NREL no date).

Mechanisms of waste settlement include mechanical compaction, raveling, consolidation, and biological and physiochemical degradation. The amount and rate of settlement vary according to a landfill's physical properties (e.g., size, waste depth, waste compaction, age), operational practices, waste contents, and waste properties (pH, temperature, organic content, moisture etc.). Generally, the greatest degree of uniform settlement occurs within several months after landfill closure; this is followed by additional uniform and differential settlement over time

(Sampson 2009; Stafford et al. 2011; Edil and Berthouex 1990). Landfills that stopped accepting waste at least 10 years before solar array construction are generally not affected by primary settling of waste, thanks to biodegradation and compression (MassDOER 2012). The EPA and NREL suggest a 2-3 year waiting period after closure to allow for initial settlement to occur (EPA and NREL no date).

3. Environmental and Social Considerations

Solar energy facilities sited on landfills are likely able to bypass many of the environmental and social impacts that are typical of energy installations sited on undeveloped open space (e.g., high acreage requirements, fragmentation of habitat, displacement of agriculture and recreation, etc). Nonetheless, landfill-based solar energy systems are not entirely isolated from interactions with the surrounding environment and community, and impacts on wildlife, water, and the public may occur. The potential for such impacts should be taken into consideration when siting and designing a landfill-based solar energy project.

3.1 Impervious Surfaces

Impervious surfaces are structures and ground coverings that inhibit rainwater infiltration and natural groundwater discharge (e.g., roads, sidewalks, and parking lots). Impervious surfaces contribute to detrimental environmental impacts such as increased stormwater runoff, erosion, and pollution of waterways. In the case of landfill solar development projects, impervious surfaces may include gravel roads, ballast, inverters, and pads. Solar panels are also considered impervious, but because panels are raised above the surface of the ground, there can be design strategies to mitigate the stormwater impacts posed by a system. As of the time of this writing, RIDEM was examining how to treat landfill solar projects in the context of compliance with the RIDEM Landfill Closure Program and the eleven minimum standards outlined in Section 3 of the Stormwater Design and Installation Standards Manual (RISDISM) (RIDEM, 2011), a set of management practices and water quality performance standards developed to mitigate the effects of stormwater runoff. It is recommended that project developers schedule a preapplication meeting with RIDEM to address the particulars of a specific project (Beck, Wilusz, and Walusiak December 2012. Personal communication).

3.2 Wetlands

The R.I. Freshwater Wetlands Act (R.I. Gen. Laws 2-1-18 et seq.) and its associated Freshwater Wetlands Rules and Regulations were instituted to "to preserve the purity and integrity of the swamps, marshes, and other fresh water wetlands of this state (R.I. Gen. Laws 2-1-19)." The Freshwater Wetlands Act requires landowners to obtain a permit from RIDEM in order to "excavate; drain; fill; place trash, garbage, sewage, highway runoff, drainage ditch effluents, earth, rock, borrow, gravel, sand, clay, peat, or other materials or effluents upon; divert water flows into or out of; dike; dam; divert; change; add to or take from or otherwise alter the character of any fresh water wetland (R.I. Gen. Laws 2-1-21)." Landfill solar projects located near wetlands may require freshwater wetlands permits to ensure that no adverse impacts to the wetland occur.

3.3 Impacts on Birds and Wildlife

Solar energy projects can disturb wildlife through construction noise, runoff, glare, and activities associated with maintenance work. Endangered and threatened species are of particular concern when considering these impacts. Project owners should determine whether a proposed site contains habitat of value for endangered and threatened species. The U.S. Fish and Wildlife Service (USFWS), which oversees implementation of the Endangered Species Act, currently lists seven animal and one plant species in Rhode Island as endangered, and two animal and two plant species as threatened. RIDEM's Natural Heritage Program also maintains a list of animal and plant species identified as endangered, threatened, or of concern by the state. If endangered species are present on or near landfills, solar energy development should proceed in accordance with the Endangered Species Act (ESA; 16 U.S.C. § et seq.) of 1973. The ESA makes it unlawful for any person in the United States to "take" an endangered species. To "take" is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct (16 U.S.C. § 1532)."

Some evidence suggests that solar panels can affect the ability of birds to carry out migratory activity, but little is known about this relationship. Panel glare is probably the most important factor to consider, but mitigation of glare is difficult to achieve (Sheppard 2012. Personal communication). Use of night-time safety lights, especially steady red or white lights, may also be disorienting for birds (Sheppard 2011). Migrating birds are most affected by lights during stormy weather, so it may be prudent to reduce the extent of lighting associated with PV panels during periods of inclement weather activity. For added protection, project owners may consider permanent use of cut-off shields, which direct light downward, and motion detectors on all facility lights.

3.4 Human Safety

Because utility-scale PV facilities generate large amounts of electricity and contain potentially hazardous wiring, they may present a human safety hazard if not managed with precaution. Additionally, all PV components, including the panels, which are made of glass, must be protected from damage caused by human interference. Erecting fences around landfill solar projects can serve the dual purpose of keeping the public safe from electrical hazards and protecting the panels from vandalism or theft. This consideration may limit the size of PV arrays on landfill sites because there must be buffer space between the fencing and the panels.

A separate human safety factor involves glare from the solar array. Glare from panels can potentially disrupt pilots along airport flight paths. Glare can usually be mitigated via minor tilt adjustments (Stafford et al. 2011).

3.5 Cultural and Historic Resources

While landfills are unlikely to be considered historic or cultural sites themselves, development of solar energy projects on landfills can have indirect impacts on historic or cultural sites in the vicinity. Indirect effects on a historic or cultural site are those that infringe on the use of that site by introducing a foreign structure into the viewshed and/or creating noise impacts that interfere with appreciation of the site's cultural or historic value. For instance, glare caused by solar panels or noise caused by construction may diminish the ability of the public to appreciate historic or cultural sites near a project.

The historic and cultural environment around a landfill may include archaeological remains, historic buildings, cemeteries, sites of sacred importance to Native American cultures, and traditional landscapes. Many cultural resources are unique and irreplaceable, but some may require more protection than others. For instance, sites that receive more visitors are arguably more important to protect than less popular or well known sites (Masser 2006).

Rhode Island has a dense concentration of sites of historic and/or cultural value. According to the Rhode Island Historical Preservation and Heritage Commission,

> "From sites yielding evidence of prehistoric encampments, to eighteenth-century farms, to commercial buildings of the early twentieth century, our history can be traced by what remains on the landscape. The preservation of these remnants helps us to retain our sense of history and community. It also aids in the education of our children and our new residents by showing them, through the history embodied in their everyday surroundings, the depth and breadth of our common heritage (RIHP&HC 2012)."

Many jurisdictions have a process for cataloging and protecting heritage sites in Rhode Island. These include the National Register of Historic Places, the Rhode Island Historical Preservation and Heritage Commission, municipalities' local historic districts, the Narragansett Indian Tribal Historic Preservation Office, and local preservation societies. All of these entities may be helpful sources of information when considering the potential historic and cultural impacts of a solar energy installation.

3.6 Public Acceptance

Public acceptance is an important yet hard-to-predict variable in the siting of solar energy projects on capped landfills. Although landfills arguably present a public acceptance issue in themselves, it should be recognized that capped landfills are designed to be as innocuous as possible. Thus, the addition of solar energy installations to landfill caps may present new impacts that affect quality of life in the immediate vicinity. Potential impacts relevant to public acceptance include competition with other adaptive reuse interests (discussed in Section 2.4.1), visual impacts, and acoustic impacts, as well as the environmental impacts discussed throughout this section.

Visual impacts are perhaps the most salient impact related to public acceptance of landfill-based solar energy facilities. Addition of solar panels to an otherwise inconspicuous capped landfill may be seen as visually intrusive. The manmade materials and right angles typical of solar panels and laminate films may prevent solar facilities from blending seamlessly into rural or scenic landscapes. Though solar panels lack the height and moving parts associated with wind turbines, the subjective responses to these two forms of renewable energy experienced by viewers may be shaped by some of the same factors, such as character and scenic quality of a landscape (Bishop 2002; Lothian 2006; Vissering et al. 2011), topography (Vissering et al. 2011), personal feelings towards this new form of energy (Bishop 2002; Cownover et al. 2010), perceived economic benefits (Thayer and Hansen 1988), array design (Cownover et al. 2010), and perceived compatibility with the surrounding landscape (Phadke et al. 2009). Solar energy facilities sited in areas valued for their natural beauty can be expected to raise a greater level of objection from the public than those sited in areas considered less visually appealing (Tsoutsos *et al.* 2005).

Potential visual impacts can be assessed prior to project construction through visual impact assessment and public input. Visual impact assessments are systematic analyses of potential impacts to scenery resulting from a proposed development. Visual impact assessment tools can take a range of forms. The simplest are artists' sketches or altered photographs showing profile views of what a proposed facilitiy would look like within a landscape. More advanced methods include computer maps, 3-D models, animations, and interactive virtual reality environments (Macaulay 2010). A complete assessment incorporates both objective and subjective considerations and performs formal evaluations of the means available to mitigate any negative impacts (Macaulay 2010).

Other potential impacts include noise and economic considerations. In contrast to wind turbines, solar energy facilities generally do not produce enough noise to become a public nuisance. Moreover, facilities that do produce low levels of noise in their day-to-day operation are limited to doing so only during hours of sunlight and are thus unlikely to cause disruption at night when neighbors are sleeping (Tsoutsos *et al.* 2005). Public acceptance of new solar energy installations may be higher in cases where they lead to local investment and job creation and when the energy produced is available to local ratepayers at an attractive price (Heras-Saizarbitoria *et al.* 2011).

4. Legal and Regulatory Considerations

Existing policies and regulations at both the state and federal levels represent an important source of guidance on the planning and permitting of solar energy projects on closed landfills. While the majority of these policies and regulations do not specifically address this type of renewable energy project as a regulated activity, they nonetheless have a bearing on the development of such projects, particularly due to concerns about landfill use and closure. State and federal policies and regulations most relevant to the type of projects reviewed in this assessment include waste and landfill regulations, legal options for transference of landfill site control to solar energy project developers, solar access laws, and environmental laws. In addition, several state and federal incentives for renewable energy may be of interest when planning solar energy projects such as those reviewed here. Finally, local ordinances and zoning practices will play a central role in the planning and permitting of solar energy projects on capped landfills.

4.1 Federal Landfill Regulations

A variety of federal laws and regulations govern waste management and disposal at landfill sites and may be relevant when considering solar development on a landfill. Occasionally, development on a landfill may require compliance with new regulations adopted since the closure of the landfill. For instance, landfills capped many years ago may not meet current standards for caps or lining; alternatively some linings and/or caps may have lost integrity during intervening years since closure. In these cases, landfills may need to be brought up to current regulatory standards before they can be used for solar electricity generation. The two major federal laws pertaining to landfills and waste are the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

4.1.1 Resource Conservation and Recovery Act (RCRA)

Passed in 1976, RCRA (42 U.S.C. §§ 6901 et seq.) gives the Environmental Protection Agency (EPA) authority to regulate generation, transportation, treatment, storage, and disposal of hazardous and non-hazardous solid waste. Prior to the enactment of RCRA, there was little federal or state oversight of the dumping of hazardous wastes on land, and leaching of waste into public water supplies was commonplace (EPA 1976).[1]

RCRA applies to both hazardous and non-hazardous waste. Section C of RCRA pertains to hazardous wastes. It enables the EPA to track hazardous wastes form “cradle to grave”, by imposing strict reporting requirements on the generation, transport, treatment, and disposal of

[1] Interestingly, there is not a one-to-one match between the laxer regulations of pre-1970s landfills and the danger posed by hazardous waste contained in such landfills. This is because enactment of solid waste regulations coincided with increasing use and disposal of hazardous materials, primarily petrochemicals. Landfills capped prior to 1960 often contain fewer hazardous materials because petrochemicals were not as widespread in their use at that time (Dennen, personal communication).

hazardous waste. Section D pertains to non-hazardous waste, including household garbage, non-recyclable household appliances, residue from incinerated automobile tires, refuse such as metal scrap, construction and demolition debris, and sludge from industrial and municipal waste water facilities and drinking water treatment plants.

The EPA's implementing regulations for hazardous and non-hazardous waste management are found in 40 C.F.R. § 264. Section N applies specifically to landfills, and explains requirements for how a landfill must be lined, capped, and cared for after closure. RCRA enables the EPA to delegate its regulatory authority over waste activities to state agencies where appropriate. State standards must be at least as strong as federal standards for this to take place. RIDEM has been approved to carry out the RCRA program for Rhode Island.

The Hazardous and Solid Waste Amendments (HSWA) of 1984 strengthened RCRA by extending the scope of the law to cover generators, transporters, and disposers of small quantities of hazardous wastes and by banning all land-based disposal of hazardous waste except when EPA deems that it is not injurious to public health. The HSWA gave EPA the specific authority "to establish national regulations for all municipal solid waste landfills to ensure the protection of human health and the environment (40 C.F.R. § 258(a))."

The relevance of the RCRA and HSWA to the siting of solar energy facilities on landfills stems from the fact that the primary purpose of a landfill is to isolate wastes from the surrounding environment. If a particular landfill fails to comply with RCRA or any other federal or state solid waste regulation, that landfill must go through the proper procedures to be brought into compliance in order to make any secondary use, such as solar energy, financially and legally secure. RIDEM's Landfill Closure Program (LCP; discussed in Section 4.2) consolidates requirements from RCRA, Superfund, and other applicable regulations; thus, landfills obtaining a closure certificate through the LCP are also assumed to be compliant with RCRA.

4.1.2 Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund

The Comprehensive Environmental Response, Compensation, and Liability, or Superfund, Act of 1980 (42 U.S.C. §§ 9601 et seq.) obligates owners of sites contaminated with hazardous waste to perform and/or pay for a proper clean-up of these sites. Citizens, State agencies, and EPA Regional offices may recommend any contaminated site for remediation under CERCLA. EPA then conducts a Preliminary Assessment/Site Inspection (PA/SI). If the site meets the requisite criteria, EPA places it on the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), a computerized inventory of hazardous substance release sites. The most heavily contaminated sites are eligible for "Superfund" status, which is granted when they are placed on the National Priority List (NPL). Sites with NPL status are prioritized for cleanup. Once a site is placed on the NPL, EPA attempts to compel parties liable for the contamination to remove contaminants and remediate the site.

Liable parties include, in the following order: (1) the current owner of a site; (2) the owner at the time that hazardous waste was disposed of on the site; (3) the generator of the contamination (i.e., the person(s) who arranged for the wastes to be disposed); and (4) the persons who transported the waste to the site or selected the site for disposal. If EPA is not able to force any of these parties to pay for the cleanup, it may perform the cleanup itself, using a trust fund set aside specifically for clean-up of hazardous waste sites.

Secondary uses, such as solar energy development, are generally not pursued on unremediated Superfund sites, due to the lack of secure legal status surrounding these sites. Moreover, RIDEM's Landfill Closure Program (LCP) would not grant a closure certificate to an unremediated Superfund site. However, Superfund sites that have been fully remediated and certified through the LCP may present suitable conditions for solar energy development. EPA approval of this secondary use is necessary prior to development of such sites.

Ch. 2 Table 2. Rhode Island Landfills on the EPA's National Priorities List (Source: EPA 2012).

Rhode Island NPL	Location
Central Landfill	Johnston
Centerdale Manor Restoration Project	North Providence
Davis Liquid Waste	Smithfield
Davis (Gsr) Landfill	Glocester and Smithfield
Davisville Naval Construction Battalion Center	North Kingstown
Landfill And Resource Recovery, Inc. (L&Rr)	North Smithfield
Newport Naval Education/Training Center	Newport, Middletown, Portsmouth, and Jamestown
Peterson/Puritan, Inc.	Cumberland and Lincoln
Picillo Farm	Coventry
Rose Hill Regional Landfill	South Kingstown
Stamina Mills, Inc.	North Smithfield
West Kingston Town Dump/URI Disposal Area	South Kingstown
Western Sand & Gravel	Nasonville

4.2 Rhode Island Landfill Regulations

Over 100 landfills have been identified in Rhode Island (RIDEM 2001). Most are municipal and private landfills, some of which were never licensed for solid waste disposal (RIDEM 2001). All landfills in Rhode Island are subject to RIDEM's Rules and Regulations for Hazardous Waste Management and Rules and Regulations for Composting Facilities and Solid Waste Management Facilities. The latter set of regulations includes extensive descriptions of requirements for landfill engineering and operation, including stipulations on grading, erosion control, vegetation, and other aspects that might be relevant for the siting of solar energy arrays on capped landfills.

RIDEM's Office of Waste Management manages solid wastes through two programs: the Waste Management Facilities Program and the Site Remediation Program. The Waste Management Facilities Program regulates disposal and processing of solid, hazardous, and medical waste and oversees the closure of inactive landfills. The Site Remediation Program regulates investigation and remediation of releases of hazardous waste and hazardous materials into the environment.

To proceed with development of a solar installation on a capped landfill, a developer must first assure that the landfill has been officially "closed." Not all landfills in Rhode Island have completed a full closure process, and some of those without a landfill closure certificate were abandoned long before an official closure process was instituted. RIDEM's Landfill Closure Program (LCP) is a part of the Waste Management Facilities Program that serves to "streamline the investigation, remediation and closure of these inactive landfills (RIDEM 2001)." The LCP is designed as a more cost-effective and less time-consuming substitute to the traditional Superfund process, and helps landfill owners comply with the Superfund process by guiding them through an alternative process overseen by RIDEM (RIDEM 2001). The LCP applies only to landfills that ceased operation prior to April 1992. The program is based primarily on voluntary participation by municipalities, except where severe contamination compels RIDEM to intervene.

Assuring that a landfill has a closure certificate is a prerequisite for development of solar infrastructure on the landfill. To obtain formal closure at an inactive landfill, an owner must complete a closure process under the oversight of RIDEM's LCP program. The LCP program is a hybrid that relies on the regulatory authority of both the Site Remediation and Solid Waste Regulations. Compliance entails hiring a consultant to develop a Site Investigation Work Plan (SIWP), performing any necessary remediation actions as described in the Solid Waste Regulations, and undergoing annual inspections and post-closure monitoring performed by a qualified engineer to determine whether the site has been properly remediated (RIDEM 2001). This process generally takes about three years, but it can be completed in as little as two or as many as five (Benevides, personal communication).

After assuring that a desired site possesses a landfill closure certificate, a developer must obtain approval to build on the site. RIDEM retains regulatory jurisdiction over a solid waste landfill through a "perpetual conservation easement," as prescribed in RIDEM's Solid Waste Regulations. The perpetual conservation easement prohibits any disturbance or construction on a landfill without prior written consent from RIDEM. RIDEM may issue permission to a landfill owner to install solar energy infrastructure on top of a landfill as long as the development does not pose harm to the landfill cap or the surrounding environment. As a condition for approval, RIDEM may make certain stipulations regarding the technical design of the project, including considerations pertinent to the side slopes and capping system of a landfill (Benevides, personal communication).

4.3 Site Control

Site control is the process by which a project owner secures the legal rights to build on and use the land on which a project takes place. Site control is not only a guard against future legal problems, but is often a prerequisite for obtaining grants and permits (Greguras and Lewandowski 2011). Prior to beginning development, a project owner must acquire both a legal interest in the land and adequate access to the site. Both of these must be obtained from the landfill owner. Landfills may be municipally owned, privately owned, or state-owned. There are multiple legal formats that serve to secure site control. Different formats may be preferred at different stages of a project and may also be influenced by the ownership status of the land and the needs of the developer. Available legal formats for site control include option agreements, long-term lease contracts, and development easements.

During the initial feasibility assessment stage of a project, project owners may choose to pursue an option agreement with land owners. An option agreement gives the project owner the exclusive right to negotiate a potential purchase or a long-term lease of the site in the future, at an agreed-upon price and subject to agreed-upon terms. An option agreement places the property off-limits for other developers to bid on during the time that the developer is evaluating the decision to build. At the end of the option period, the developer must decide whether to negotiate further site control of the property or give up all interest in the land (Farmers' Legal Action Group 2007).

Lease agreements and development easements provide secure, long-term site control. In a lease agreement, use of a landfill property is granted to a project owner for a specified time and purpose in exchange for payments to the landfill owner. Lease agreements identify a market-rate level of compensation, specific rights reserved to the lessee, expectations of lessor/lessee cooperation and responsibility, and insurance, indemnification, and decommissioning provisions (Farmers' Legal Action Group 2007). The terms of the lease agreement can be tailored to meet the contracting parties' needs. A project developer may wish to secure a right to access the property, a right to build a solar installation and associated infrastructure, and an assurance that future development will not impact the productivity of the solar project. A landfill owner may wish to include assurances of proper site security, stipulations that a potential developer will seek permission for certain activities, and a promise to comply with federal and state regulations.

A development easement is "an interest in land owned by another person, consisting of the right to use or control the land, or an area above or below it, for a specific limited purpose (Black's Law Dictionary 2001: 405)." An easement "does not give the holder the right to possess, take from, improve, or sell that land (Black's Law Dictionary 2001: 226)."

4.4 Solar Access Laws

Although sunlight cannot be appropriated, it can be unintentionally blocked from reaching a solar panel intended to capture it. This can occur when vegetation, screening, buildings, or other constructions are erected or allowed to grow in such a way as to block the sun's rays from reaching a solar installation. Solar access laws, which may be enacted at the state and local levels, enable energy developers to insure against blockage of the solar resource that they rely on to generate power. The most common type of solar access arrangement is a solar easement.

When owners of property adjacent to a solar energy project or upon which the project is located agree to a solar easement, they volunteer to avoid building structures or planting tall trees that would obstruct the sun's rays from reaching solar installations. Rhode Island's Solar Easements law (R.I. Gen. Laws 34-40) enables property owners and solar project owners to come into agreement to protect the "solar skyspace," defined as the "space between a solar energy system and the sun which must remain unobstructed such that on any given clear day of the year, not more than ten percent (10%) of the collectible insolation shall be blocked (R.I. Gen. Laws 34-40-1)." Such agreements hold valid if ownership of either property is transferred, and may include provisions for compensation in the event that either party violates the solar access provisions of the easement.

4.5 Federal and State Solar Energy Incentives

Several state and federal policies aim to foster renewable energy projects, including solar energy, through monetary or other incentives. Recognizing that the relative novelty of most forms of renewable energy can at times act as an impediment to economic success, such incentives aim to offset the economic burden associated with installing new and unfamiliar energy technologies.

Over the years, a variety of federal incentives have been instituted to foster development of renewable energy. These are sometimes of short duration and are always subject to change, due to Congressional reauthorization processes. Solar energy is eligible for incentives under a number of federal policies promoting renewable energy. These include the Department of Energy Loan Guarantee Program, the Renewable Energy Production Tax Credit, the Public Utilities Regulatory Policy Act, and Clean Renewable Energy Bonds. Descriptions of these incentives are presented in the Wind Energy Chapter of this report.

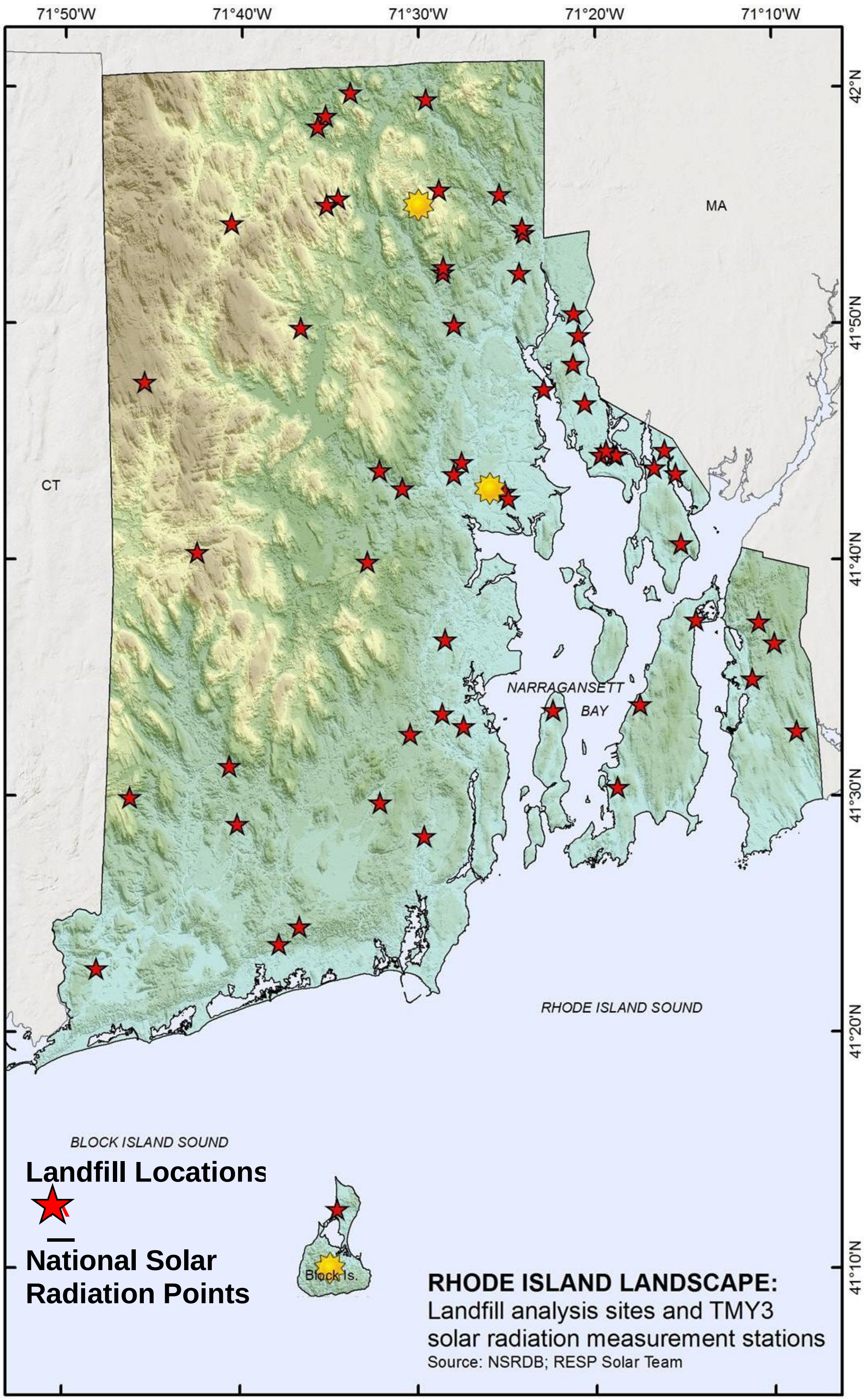
In addition, the state of Rhode Island has established a variety of incentives to spur the development of renewable energy in the state. The most significant is the Renewable Energy Standard, which guarantees a market for renewable energy by requiring electrical distribution companies to purchase a certain amount of it per year. Other incentives foster distributed generation, net metering, interconnection, and tax incentives. These incentives apply to multiple forms of renewable energy, including solar energy, and are discussed in detail in Chapter 1, Section 5 of this report.

5. Landfill Solar Resource Assessment and Screening Analysis

The RESP landfill solar screening analysis synthesizes the siting considerations above and presents them in a Rhode Island-specific context. Like the literature review imparted above, the purpose of the screening analysis was to help quantify opportunities and constraints relevant to deployment of solar energy on closed landfills in Rhode Island. The first objective of the RESP analysis was to develop simple and easy-to-use solar energy site screening tools. A secondary objective was to estimate the total amount of photovoltaic power that could be generated on suitable land at these sites. Lastly, the RESP analysis sought to identify landfills likely suitable for generating at least 1 MW of solar power (generally considered to be utility-scale).

The RESP analysis may be used to inform landfill solar decision making processes at three levels. First, site screening tools can be used to identify which landfills are good candidates for solar development and what are the barriers and opportunities related to deploying solar energy at various landfill locations. Second, order-of-magnitude solar energy estimates for landfills can help alert municipal officials to solar development opportunities on sites in their respective towns. Lastly, higher-resolution data characterizing available landfill solar resources and site suitability can help support decision-making at the statewide level for resource management agencies and policy makers. The following section summarizes the RESP landfill solar screening analysis; the complete study is contained in RESP Volume 2.

To estimate total and site-specific landfill solar resources in Rhode Island, RESP researchers worked with the Rhode Island Department of Environmental Management (RIDEM) Landfill Closure Program (LCP) to identify a complete list of 87 existing landfill sites in the state. All of these sites are closed and no longer accept waste, with the exception of the Central Landfill and the Tiverton Landfill. Because many of these sites (particularly smaller municipal dump and landfill sites) have not operated for years, the exact delineation of the waste disposal area is often unknown, unavailable, or not easily accessible. Because quantification of solar resource and site suitability requires study sites to have defined boundaries, RESP researchers decided to rely on GIS parcel data to perform the screening analysis. Thus, the study targeted a total of 58 sites (comprising 2,787.6 acres) for which parcel data was available.



Ch. 2 Figure 11. Rhode Island Landfill Sites and Solar Measurement Stations.

Once parcel data was obtained for all 56 landfill sites, RESP researchers used a two-pronged approach to quantify the total area at each site that may be appropriate for solar development. First, they developed GIS-based "first-cut" site screening criteria to help characterize the areas in each landfill parcel that appear most compatible with solar development. The main criteria informing this step were slope and land use class. The slope screening criterion was used to eliminate land areas with steep gradients that likely would pose structural and design challenges for a landfill ground-mounted PV array. RESP researchers used two slope scenarios—the first, more conservative (excluding all areas with a slope greater than 3%); the second, less conservative (excluding all areas with a slope greater than 6%). The land use class criterion was used to describe the on-the-ground land use at each landfill parcel. For the purposes of the RESP screening analysis, land use classes considered appropriate for solar PV development included waste disposal, vacant/barren, brushland, and agricultural use.

Having isolated areas in each landfill parcel exhibiting appropriate slopes and land use characteristics, RESP researchers calculated the amount of PV capacity (in megawatts) that could be produced on these areas. Because the capacity of a PV array is directly related to the number and design features of panels in that array, researchers made a series of assumptions regarding panel type, tilt, and packing factor (a parameter describing the space requirements around PV panels to account for maintenance, accommodate equipment, and mitigate shading effects). Under the set of relatively conservative assumptions used in the RESP screening analysis, Rhode Island landfills need approximately 6.6 acres of area to generate 1 MW of photovoltaic power. Using this figure as an indicator of the relationship between acreage and solar energy production potential, RESP researchers were able to generate estimates for site-specific and total landfill solar resources on flat areas with appropriate land uses for solar development.

The results of the RESP screening analysis demonstrated that a potentially significant amount of solar power could be generated on Rhode Island landfills. Gently-sloped areas on all landfill parcels could support a grand total of 391 MW of estimated potential power. Restricting this area to only "appropriate" land use classes reduces the total amount of estimated potential power to 110 MW. The RESP analysis, however, found that solar resources are distributed unevenly across the different land use classes: for example, forested areas account over half of the area in landfill parcels; such areas could support PV arrays only if this growth was cut down. In total, 37 sites were found to have the potential for at least 1 MW of photovoltaic solar generating capacity.

The first-cut screening analysis performed by the RESP helped establish a first-order estimate of acreage on Rhode Island lands that could support solar. Despite high solar potential, however, a landfill may not be immediately suitable for solar development. For example, even if a landfill parcel contains a large amount of vacant area on a gently sloping southern exposure, this area, may have been developed into athletic fields, or the landfill may be unreasonably far from a connection point to the electrical distribution grid. Another situation to consider is that a waste disposal site may not be currently capped according to RIDEM standards, and could possibly require some form of remediation before development.

Therefore, study sites were further classified by several additional site suitability characteristics identified in partnership with RIDEM. These measures of site suitability help gauge the ease of bringing high-potential sites to "shovel-ready" status for solar development. The RESP research team compiled a comprehensive spreadsheet detailing the status of each site in terms of: presence/type of landfill cap, current use, interconnection feasibility, and site control. The results can be found in the appendices in the Volume 2 Technical Report.

6. References

ASCE. 2005. Figure 7-1: Ground Snow Loads, pg, for the United States (lb/ft2) in: Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers, 420 p.

ASTM International. 2012. "E1038-10 Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls," West Conshohocken, PA, 2005, DOI: 10.1520/E1038-10. Available online at: astm.org/Standards/E1038.htm. Last accessed April 2012.

Atney, I., Davis, M., Goode, G., Gordon, R., Green, T., Higbie, J., Hooda, B., Lee, R., Paquette, D., Polanish, C., Toscano, M., Williams, J. 2009. Environmental Assessment for BP Solar Array Project, Brookhaven National Laboratory, Upton, New York. US Department of Energy Office of Science DoE / EA – 1663, 68 p.

ATSDR. 2001. Landfill Gas Primer: An Overview for Health Professionals. Agency for Toxic Substances and Disease Registry: Department of Health and Human Services, Division of Health Assessment and Consultation. 74 p.

Barton and Loguidice, P.C. 2011. Solar Landfill Closure Project: First Municipal Landfill Solar Cap in the Country. Available online at: bartonandloguidice.com/Services/SolidWaste/SolidWastePortfolio/tabid/291/Default.aspx. Last accessed March 9, 2012.

Bishop, Ian. 2002. Determination of thresholds of visual impact: the case of wind turbines. Environment and Planning B: Planning and Design. Vol. 29, Issue 5. pp. 707-718.

Black, H.C. 2001. Black's Law Dictionary. 2nd edition. St. Paul, Minn.: West Publishing. Available online at: http://blacks.worldfreemansociety.org/2/index.htm. 1,314 p.

Booz, Allen, and Hamilton. 2007. Renewable Energy Enhanced Use Lease Opportunity Summary Report. Washington, DC: Air Force Real Property Agency, August 2007. 49 p.

Brown, N. 2011. "Solar Junction Breaks Concentrated Solar World Record with 43.5% Efficiency." CleanTechnica.com: April 19, 2011. Available online at: http://cleantechnica.com/2011/04/19/solar-junction-breaks-concentrated-solar-world-record-with-43-5-efficiency/

CAEC. 2012. "Landfill Gas Power Plants." California Energy Commission. 2 p. Available online at: energy.ca.gov/biomass/landfill_gas.html

CES. 2011(a). Spectro PowerCap Hickory Ridge Case Study. Carlisle Energy Services, Carlisle, PA: September 2011. Available online at: http://m.waste360.com/landfill-solar-projects/look-hickory-ridge-landfill-solar-installation

CES. 2011(b). Spectro PowerCap Madison County Case Study - 605899. Carlisle Energy Services, Carlisle, PA: November 2011.

Conti, J.J., Holtberg, P.D., Beamon, J.A., Schaal, A.M., Sweetnam, G.E., Kydes, A.S. 2008. Annual Energy Outlook 2008 – with Projections to 2030. Energy Information Administration, DOE/EIA-0383(2008). June 2008. Available online at: eia.gov/oiaf/aeo/pdf/0383(2008).pdf

Cownover, B., Thayer, R., Ryan, R., and Sheppard, S. 2010. Wind Energy on the Horizon: The New Energy Landscape. October 7, 2010. Available online at: http://www.massland.org/files/Wind_energy_horizon_new_landscape.pdf

DoE. 2011(a). "Energy Basics – Flat-Plate Photovoltaic Systems." US Department of Energy – Energy Efficiency and Renewable Energy Program. Washington, DC: Last updated August 12, 2011. Available online at: eere.energy.gov/basics/renewable_energy/flat_plate_pv_systems.html

DoE. 2011(b). "Energy Basics - Photovoltaic System Performance." US Department of Energy – Energy Efficiency and Renewable Energy Program. Washington, DC: Last updated August 12, 2011. Available online at: eere.energy.gov/basics/renewable_energy/pv_system_performance.html

DoE. 2011(c). "Energy Basics - Photovoltaic Systems." US Department of Energy – Energy Efficiency and Renewable Energy Program. Washington, DC: Last updated August 12, 2011. Available online at: eere.energy.gov/basics/renewable_energy/pv_systems.html

Edil, T.B., and Berthouex, P.M. 1990. Earthen Barriers Technology for Waste Containment. Waste Management, Vol. 10, Issue 2. pp. 147-153.

EPA and NREL. no date. RE-Powering America's Land Initiative: Solar Photovoltaic Decision Tree. Environmental Protection Agency - Office of Solid Waste and Emergency Response (OSWER) and National Renewable Energy Laboratory, 18 p. Available online at: epa.gov/oswercpa/docs/solar_decision_tree.pdf

EPA. 1993. Engineering Bulletin: Landfill Covers. Environmental Protection Agency - Office of Research and Development, Cincinnati, February 1993. EPA/540/S-93/500. 8 p. Available online at: http://nepis.epa.gov/Exe/ZyNET.exe/10002DT7.txt?ZyActionD=ZyDocument&Client=EPA&Index=1991%20Thru%201994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C91THRU94%5CTXT%5C00000006%5C10002DT7.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1

EPA. 2011(a). Data Guidelines for "Renewable Energy Generation Potential on EPA and State Tracked Sites" [Map]. Environmental Protection Agency - Office of Solid Waste and Emergency Response (OSWER) Center for Program Analysis, 17 p. Available online at: epa.gov/renewableenergyland/maps/epa_tracked_sites_data_guidelines.pdf

EPA. 2011(b). Policy Driven and/or Utility Scale Photovoltaic (PV) Solar Energy Generation Potential Maps. US Environmental Protection Agency, RE-Powering America's Land Initiative. Last updated November 4, 2011. Available online at: epa.gov/renewableenergyland/maps_utility_pv.htm. Last accessed March 15, 2012.

EPA. 2011(c). Re-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites – Anywhere the Sun Shines: Developing Solar Energy on Contaminated Land. Environmental Protection Agency: November 7, 2011. 2 p. Available online at: epa.gov/oswercpa/docs/solarmarket_analysis_overview.pdf

EPA. 2012(a). Current LMOP Landfill and LFG Energy Project Database – Rhode Island. US Environmental Protection Agency - Landfill Methane Outreach Program. Last updated April 26, 2012. Available online at: epa.gov/lmop/projects-candidates/index.html. Last accessed June 25, 2012.

EPA. 2012(b). Landfill Methane Outreach Program. Environmental Protection Agency. Last updated June 14, 2012. Available online at: epa.gov/lmop/index.html. Last accessed June 25, 2012.

EPA. 2012(c). Re-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites. Environmental Protection Agency. Last updated April 20, 2012. Available online at: epa.gov/oswercpa/

EPA. 2012(d). "Waste Site Cleanup & Reuse in New England - Superfund." Last updated May 1, 2012. Available online at: http://www.epa.gov/region1/superfund. Last accessed April 19, 2012.

Greguras, F. and Lewandowski, S. 2011. Climate Change Report: The Importance of Solar Project Site Control Issues. K&L Gates LLP: November 15, 2011. Available online at: http://www.climatelawreport.com/2011/11/articles/the-importance-of-solar-project-site-control-issues. Last accessed April 20, 2012.

Heras-Saizarbitoria, I., Cilleruelo, E., and Zamanillo, I. 2011. Public acceptance of renewables and the media: an analysis of the Spanish PV solar experience. Renewable and Sustainable Energy Reviews. Vol. 15, Issue 9. pp. 4685-4696.

Kennedy, J. 2012. Personal communication with John Kennedy of National Grid, Interconnection. March 2012.

Lothian, A. 2006. Visual Impact Assessment of Wind Farms in South Australia. Presented at: New Zealand Association for Impact Assessment Conference, Dunedin, New Zealand, November 30, 2006. Available online at: http://www.scenicsolutions.com.au/Attached%20PDFs/Visual%20Impact%20Assessment%20of%20Wind%20Farms%20in%20South%20Australia.pdf

Macaulay Land Research Institute. 2010. Visual Impact Assessment. Last updated May 4, 2010. Available online at: http://www.macaulay.ac.uk/ccw/task-three/via.html

MassDEP. 2011(n). Scituate Landfill Post-Closure Use - Major Solar Photovoltaic Array Permit Application letter # X238383. Massachusetts Department of Environmental Protection: September 9, 2011. 12 p. Available online at: mass.gov/dep/energy/lfpcu.htm

MassDEP. 2012(a). Adams Landfill Post-Closure Use – Solar Power Permit Approval letter # X239197. Massachusetts Department of Environmental Protection: January 5, 2012. 9 p. Available online at: mass.gov/dep/energy/lfpcu.htm

MassDOER. 2012. The Guide to Developing Solar Photovoltaics at Massachusetts Landfills. Massachusetts Department of Energy Resources, 38 p.

McAllen, J.J. 2012. Personal communication with John J. McAllen, Designer at Carlisle Energy Services. April 11, 2012.

Mendelsohn, M., Lowder, T., and Canavan, B. 2012. Utility-Scale Concentrating Solar Power and Photovoltaics Projects: A Technology and Market Overview. National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Technical Report NREL/TP-6A20-51137. April 2012. Available online at: http://www.nrel.gov/docs/fy12osti/51137.pdf

NCDC. 2012. "Temp; Extreme Maximum; by Month 376698/14765, Providence TF Green Ap Rhode Island." National Climatic Data Center, National Oceanic and Atmospheric Administration. Available online at: http://www7.ncdc.noaa.gov/CDO/cdoextremesdata.cmd. Last accessed May 4, 2012.

NHC. 2012. "The Inland Wind Model and the Maximum Envelope of Winds." Last updated March 1, 2012. National Hurricane Center, National Oceanic and Atmospheric Association, 2012, Miami, FL. Available online at: nhc.noaa.gov/HAW2/english/wind/wind_decay.shtml

NREL. 2011(a). "Derate Factors for AC Power Rating at STC." National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Last updated: June 6, 2011. Available online at: nrel.gov/rredc/pvwatts/changing_parameters.html#dc_rating. Last accessed March 21, 2012.

NREL. 2011(b). PVWatts (Version 1). Golden, CO: National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Retrieved February 15, 2012. Available online at: nrel.gov/rredc/pvwatts/

NREL. no date(a). "Glossary of Solar Radiation Resource Terms." National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Available online at: rredc.nrel.gov/solar/glossary/. Last accessed April 26, 2012.

NREL. no date(b). "National Solar Radiation Data Base - 1991-2005 Update: Typical Meteorological Year 3." Renewable Resource Data Center - National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Available online at: rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

NREL. no date(c). "National Solar Radiation Data Base." Renewable Resource Data Center - National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Available online at: rredc.nrel.gov/solar/old_data/nsrdb/

Paquet, J.R. and Beck, E. 2012. Personal communication with Jenny R. Paquet, Town of West Greenwich and Eric Beck, RIDEM. March 2012.

Parish, J. 2009. Image of Tracking Array #3 – northeast-most tracker in: "Archive for the Solar Power Category." 5 Feb 2009 entry. Last updated March 31, 2009. Available online at: wizbandit.wordpress.com/category/solar-power/. Last accessed April 23, 2012.

Phadke, R., Manning, C., Diebolt, A., and Kazinka, M. 2009. Wind Energy and Scenic Considerations in Wyoming: Workshop Report. Macalester College: August 4, 2009. Available online at: http://www.macalester.edu/windvisual/workshops/WindEnergyScenicConsInWY.pdf

PPL. 2008. Pennsauken Renewable Energy Park. People's Power and Light Renewable Energy: October 2008. 1 p.

PPL. 2010. Image of ground-mounted solar array in: "PPL Renewable Energy, Mid-Atlantic region: solar, landfill methane and wind." People's Power and Light Renewable Energy. Available online at: http://ppl.thedigitalcenter.com/assets/show/8297-ppl-renewable-energy-mid-atlantic-region-solar-landfill-methane-and-wind?linkback=1. Last accessed April 23, 2012.

Prweb.com. 2012. Image of solar racks. Available online at: http://ww1.prweb.com/prfiles/2011/08/19/8854501/fs-system.jpg. Last accessed April 23, 2012.

Republic Services. 2010. Roosevelt Regional Landfill Energy Recovery Facility. Klickitat County, Klickitat Public Utility District, and Allied Waste, Bellevue, WA. Available online at: rabanco.com/regional_landfill/default.aspx

RIDEM. 2007. Closure Policy for Inactive or Abandoned Solid Waste Landfills. Rhode Island Department of Environmental Management – Office of Waste Management. Policy Number WM-SW-2007-02. 2nd Revision (March 2001). 6 p. Available online at: dem.ri.gov/programs/benviron/waste/pdf/landclos.pdf. Last accessed April 27, 2012.

RIDEM. 2011. RI Stormwater Design and Installation Standards Manual. Rhode Island Department of Environmental Management – Office of Water Resources. Last updated September 15, 2011. Available online at: dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/t4guide/desman.htm

RIRRC. 2011. Board meeting handout on solar power capping. Rhode Island Resource Recovery Corporation: March 4, 2011. 7 p.

Roberts, W. 2008. Photovoltaic Solar Resource of the United States [Map]. "Solar Maps." National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy: 20 October 2008. Available online at: nrel.gov/gis/solar.html. Last accessed March 20, 2012.

Salasovich, J., and Mosey, G. 2011. Feasibility Study of Solar Photovoltaics on Landfills on Puerto Rico. Technical Report NREL/TP-6A20-52181. National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy, August 2011. 88 p. Available online at: nrel.gov/docs/fy11osti/52181.pdf

Sampson, G. 2009. Solar Power Installations on Closed Landfills: Technical and Regulatory Considerations. Environmental Protection Agency, 30 p.

Sanyo Corp. 2008. HIT Power 200 Photovoltaic Module Specifications. Sanyo Energy (USA) Corp. - Solar Division. Frisco, TX: July 1, 2008. Available online at: solarelectricsupply.com/pdf/Sanyo/Sanyo-HIT-200-RZ.pdf

Sargosis Solar & Electric. no date. "Irradiance vs. Insolation." Available online at: sargosis.com/articles/science/intro-guide/irradiance-vs-insolation/. Last accessed 2012.

Sewall, A. 2011. "Size of U.S. Solar Home PV Systems Growing, IREC Industry Report Says." GetSolar.com: June 30, 2011. Available online at: getsolar.com/blog/size-of-u-s-solar-home-pv-systems-growing-irec-industry-report-says/18107/

Sheppard, C. 2011. Bird-Friendly Building Design. American Bird Conservancy and New York City Audubon Society. The Plains, VA, 58p. Available online at: http://www.abcbirds.org/abcprograms/policy/collisions/pdf/Bird-friendlyBuildings0112.pdf

Sheppard, C. 2012. Personal communication with Christine Sheppard, Bird Collisions Campaign Manager at American Bird Conservancy. February 24, 2012.

Shoemaker, J.A., Brekken, C.A., Krub, K.R. 2007. Farmers' Guide to Wind Energy: Legal Issues in Farming the Wind. Farmers' Legal Action Group, St. Paul, MN: June 2007. Available online at: http://flaginc.org/topics/pubs/wind/FGWEcomplete.pdf. Last accessed April 28, 2012. 272 p.

SolarDesignTool.com. 2012. Solyndra SL-200-220 (220W) solar panel specifications. Available online at: http://www.solardesigntool.com/components/module-panel-solar/Solyndra/SL-200-220/specification-data-sheet.html;jsessionid=FB659F9291306714757547CA740DEAF8. Last accessed March 14, 2012.

SolFocus. 2008. A Primer on CPV Technology. Mountain View, CA: SolFocus, Inc. March 2008. SF-CPVP-V1-4-08.

SolFocus. 2012. "SolFocus Technology Highlights." Available online at: solfocus.com/en/technology/. Last accessed April 17, 2012.

Stafford, B., Robichaud, R., and Mosey, G. 2011. Feasibility Study of Economics and Performance of Solar Photovoltaics at Massachusetts Military Reservation. National Renewable Energy Laboratory Technical Report NREL/TP-6A20-49417, 29 p.

Tansel, B., Marin, V.L., Varala, P.K., Yildiz, B.S. 2010. Closed Landfills as Power Parks: Technical and Economic Feasibility of Solar Energy Harvesting at Florida's Closed Landfills. University of Florida - Hinkley Center for Solid and Hazardous Waste Management, 225 p.

Thayer, R.L. and Hansen, H. 1988. Wind on the land. Landscape Architecture Vol. 78, Issue 2. pp. 68-73.

Tsoutsos, T., Frantzeskaki, N., and Gekas, V. 2005. Environmental impacts from the solar energy technologies. Energy Policy. Vol. 33, Issue 3. pp. 289–296.

Van Deuren, J., Lloyd, T., Chhetry, S., Liou, R., Peck, J. 2002. Remediation Technologies Screening Matrix and Reference Guide, 4th Edition. Federal Remediation Technologies Roundtable: January 2002. Available online at: frtr.gov/matrix2/section4/4-27.html

Vissering, J., Sinclair, M., and Margolis, A. 2011. State Clean Energy Program Guide: A Visual Impact Assessment Process for Wind Energy Projects. Clean Energy States Alliance: March 2011. Available online at: http://cbuilding.org/sites/cbi.drupalconnect.com/files/CESA_Visual%20Impacts_Methodology_032111.pdf. 55 p.

Weather Channel. 2012. "Monthly Weather for Warwick, RI." Available online at: http://www.weather.com/weather/wxclimatology/monthly/USRI0063. Last accessed April 30, 2012.

Wikipedia. 2012. "List of U.S. states by population density." Last updated June 26, 2102. Available online at: en.wikipedia.org/wiki/List_of_U.S._states_by_population_density#cite_note-PopEstUS-0

Wilcox, S. and Marion, W. 2008. Users Manual for TMY3 Data Sets. National Renewable Energy Laboratory – US Department of Energy, Office of Energy Efficiency and Renewable Energy. Technical Report NREL/TP-581-43156. May 2008. 51 p. Available online at: nrel.gov/docs/fy08osti/43156.pdf

RENEWABLE ENERGY SITING PARTNERSHIP

CHAPTER 3. HYDROPOWER

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

Rhode Island's 1,420 miles of rivers represent a potential source of renewable energy. Over 742 dams already exist on Rhode Island rivers (RIDEM 2011a). Found in virtually every state waterway, these dams were built for a variety of purposes, including powering mill machinery, providing flood control, enhancing wildlife restoration, and imparting recreational opportunities to residents. While some of Rhode Island's dams continue to perform their original purpose, many now sit idle and no longer serve their original intent. The RESP hydropower analysis was tasked with evaluating a potential new use for these dams: hydroelectric energy production.

The RESP analysis explored the potential for hydropower development in Rhode Island from two angles. The first was a technical resource assessment quantifying estimated power production capacity at existing dam sites in the state. The second involved cataloging the environmental, cultural, economic, and regulatory considerations pertinent to retrofitting Rhode Island's historical dams for hydropower electric generation. The first line of analysis was underpinned by original research performed by URI scientists; the second was informed by both a literature review and an extensive stakeholder process.

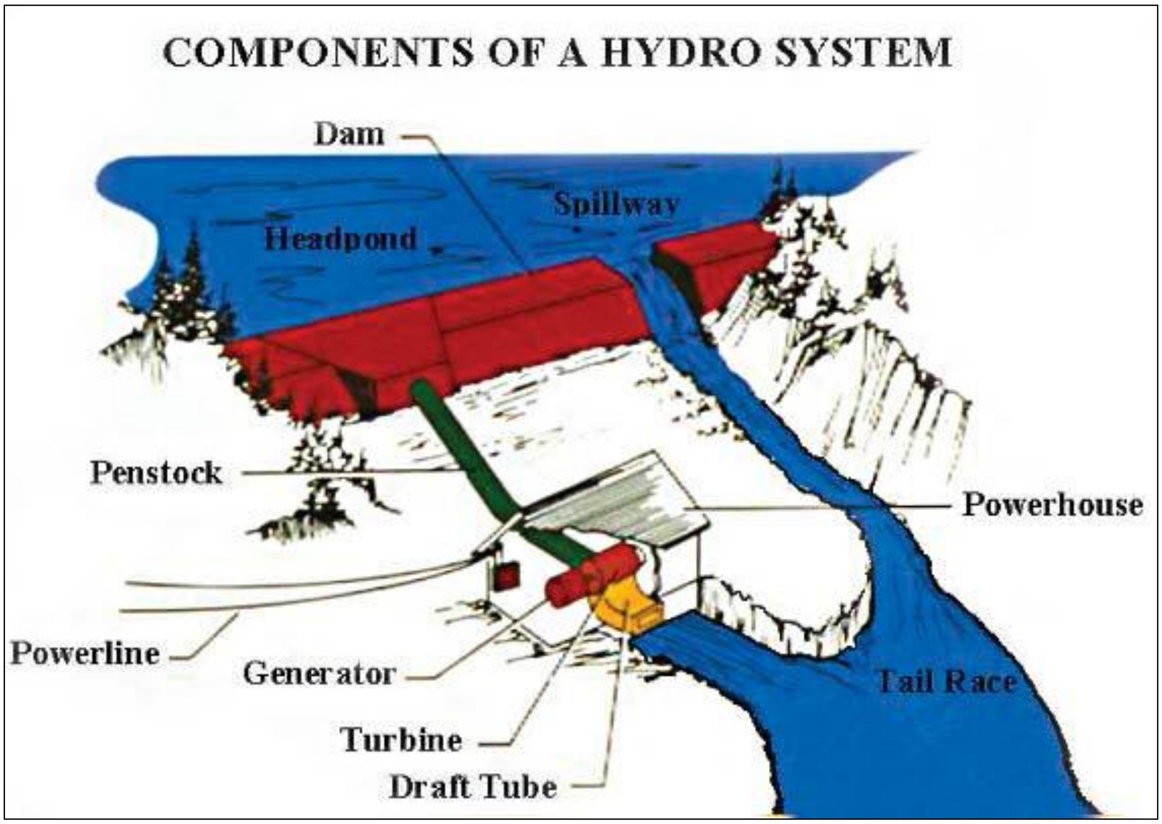
Proponents of hydroelectric power cite that it is a zero-emissions source of renewable energy, while others raise concerns about obstruction of fish passage, alteration of water quality, safety issues, and other potential conflicts that may occur when increased hydroelectric power is pitted against alternative priorities for river use. The purpose of the RESP hydropower study was to carefully evaluate multiple perspectives on hydroelectric power, and to identify both opportunities and constraints to further development of hydropower in Rhode Island.

In contrast to wind and solar energy production, hydropower is a well-established industry dating to the late 19th century. Hydropower provides the bulk of renewable energy generated in the United States (NREL 2011). In 2000, about 7-12% of total U.S. energy was derived from hydropower (INL 2001). In Rhode Island, hydropower facilities currently produce less than 0.1% of the state's electricity generation needs annually[1]. facilities (Energy Information Administration 2012). The hundreds of dams in Rhode Island that are not producing electricity may represent untapped potential.

Hydroelectric systems work by harnessing the energy of water flowing downstream to produce electricity (Ch. 3 Figure 1). Systems are engineered so that flowing water turns a turbine, which transforms the energy of water into rotational energy used to drive an electrical

[1] The Energy Information Administration's Report "State Renewable Electricity Profiles 2010" (2012) summarizes renewable electric power industry statistics for Rhode Island, based data from national surveys of electric generators with nameplate capacities of 1 MW or greater. In 2010, net hydropower generation in Rhode Island totaled approximately 4,000 MWh out of a total electricity net generation of 7,739,000 MWh. Additional information on the portion of in-state hydropower generation formally contributing to meeting the state's Renewable Energy Standard can be found in the Annual RES Compliance Reports, readily available via the RIPUC website: http://www.ripuc.org/utilityinfo/res.html.

generator. The simplest hydroelectric systems are run-of-the-river systems, which use the natural flow of a river to turn a turbine. Although they may use dams to increase the height from which water falls (known as hydraulic head; see Section 2.1), run-of-the-river systems do not alternately store and release water for times of peak demand. This strategy differs from larger and more complex systems that rely on an impoundment to store water, enabling control over production of energy to respond to fluctuations in electricity demand. A third type, pumped storage systems, uses energy to pump water uphill into a reservoir for use at a time of peak energy demand. A diversion system is a fourth type of hydropower set-up that reroutes part of a river's flow through a turbine outside of the natural flow of the river. For the most part, Rhode Island's current hydropower facilities operate as run-of-the-river facilities, and any future facilities are expected to do so as well.



Ch. 3 Figure 1. Components of a Hydro System (Source: RETScreen® Engineering and Cases Textbook).

The RESP hydropower analysis focused on low-head hydropower. Low-head hydro may be broadly defined as a change in elevation between the water above the dam and the water downstream of the dam of less than 10 ft (3 m). Most Rhode Island dam sites can be considered low-head. Located on the coastal plain, Rhode Island's rivers rarely experience drastic changes in elevation. This geographic reality, combined with a prevalence of smaller rivers, means that

Rhode Island possesses more limited hydroelectric resources than some other regions, such as the western U.S. (RIDEM 2012).

Despite modest hydroelectric resources, commercial hydroelectric production does occur in Rhode Island at present. At the time of this writing, there are seven FERC-permitted hydroelectric facilities in Rhode Island. Five facilities are operational, while one is not yet operating and one is no longer operating. All facilities are licensed to operate through a FERC license (Ch. 3 Table 1) or a FERC exemption (Ch. 3 Table 2) (See Section 4.1.1 for an explanation of FERC licensing). These facilities constitute a combined maximum permitted generating capacity of 6.7 MW (based on FERC 2012); the State's total net electricity capacity in 2010 was 1,782 MW (Energy Information Administration 2012), and historical peak load in Rhode Island was 1,932 MW as of 2012 (National Grid). In addition, six proposals to construct new hydropower facilities in Rhode Island were recently filed with the Federal Energy Regulatory Commission and preliminary permits were issued (Ch. 3 Table 3; FERC 2012). These new proposals signal a growing interest in tapping Rhode Island waterways for hydroelectric production (RIDEM 2012).

Ch. 3 Table 1. Licensed Hydropower Facilities in Rhode Island (Source: FERC 2012).

Project name	Issue date	Licensee	Waterway	Licensed capacity (kW)
WOONSOCKET FALLS	11/06/80	WOONSOCKET CITY OF (RI)	BLACKSTONE RIVER	1100
ARCTIC	01/25/83	NATCO PRODUCTS CORP (RI)	PAWTUXET RIVER	478
TUPPERWARE	10/24/80	BLACKSTONE HYDRO INC (MD)	BLACKSTONE RIVER	2000
CENTRAL FALLS	08/28/81	BRUNER/COTT INC (MA)	CENTRAL FALLS	818

Ch. 3 Table 2. Hydropower Exemptions in Rhode Island (Source: FERC 2012).

Project name	Issue date	Licensee	Waterway	Licensed capacity (kW)
PAWTUCKET NUMBER 2	07/21/81	BLACKSTONE VALLEY ELECTRIC CO (RI)	BLACKSTONE RIVER	1675
ROYAL MILLS	03/26/09	SBER ROYAL MILL, LLC.	SOUTH BRANCH PAWTUXET RIVER	225
SLATERSVILLE	12/20/10	SLATERSVILLE HYDRO, LLC	UPPER SLATERSVILLE RESERVOIR	360

Ch. 3 Table 3. Hydropower facilities in RI with issued FERC preliminary permits (Source: FERC 2012).

Project name	Issue date	Licensee	Waterway	Licensed capacity (kW)
SWIFT RIVER MILL	10/26/09	RENEWABLE RESOURCES, INC.	PAWCATUCK RIVER	390
MANVILLE	04/01/11	VALLEY AFFORDABLE HOUSING CORP	BLACKSTONE RIVER	1026
WEBBING	10/21/11	RHODE ISLAND DEPT OF ENV MANAGEMENT	BLACKSTONE RIVER	745
ALBION DAM	09/15/11	ALBION HYDRO, LLC	BLACKSTONE RIVER	1200
ASHTON DAM	09/15/11	ASHTON HYDRO, LLC	BLACKSTONE RIVER	1000
HUNT'S MILL DAM	02/08/12	CITY OF EAST PROVIDENCE	TEN MILE RIVER	300

Due to the characteristics of the surrounding terrain, Rhode Island's dams fall within the designations of micro-hydro and small-scale hydro. Micro-hydro facilities produce less than 100kW of power and small-scale facilities produce between 101 kW and 30 MW of power (NREL 2001). The RESP focused on opportunities and potential impacts associated with hydropower facilities larger than 100kW (i.e., small-scale hydro). This cutoff was selected because facilities of this size are assumed to be grid-tied, large enough to pose potentially significant alterations to natural or cultural systems, and eligible for assisting the State in meeting statutory renewable energy targets. Although still subject to many of the same regulations as small-scale hydro, micro-hydro generation often involves a different set of potential impacts and technological solutions, and may or may not be grid-tied.

2. Rhode Island Hydropower Resource Assessment

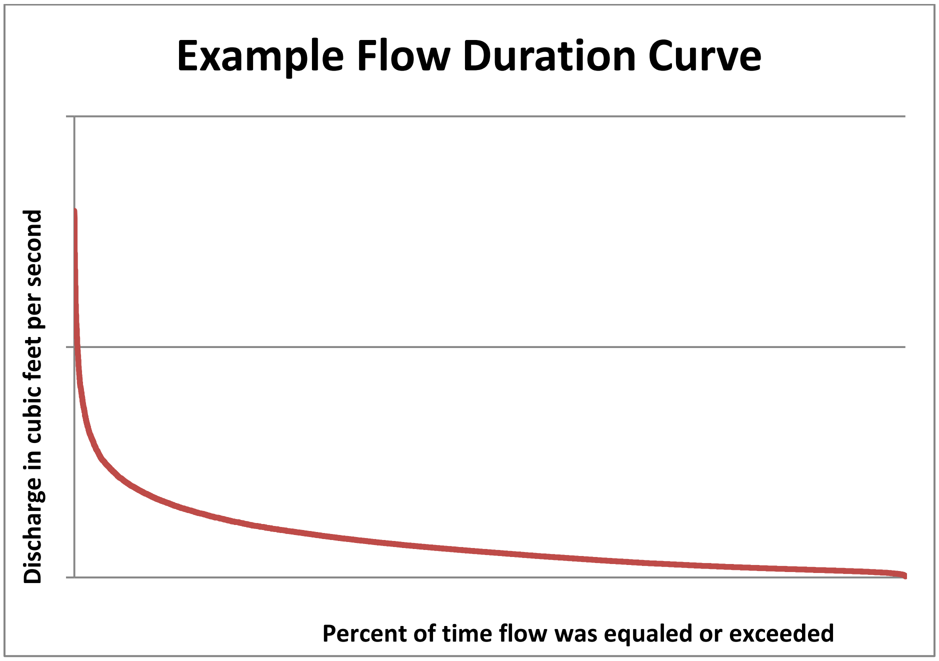
The purpose of the RESP hydropower resource assessment was to further constrain previous estimates of available hydropower resources in Rhode Island waterways. The results of this analysis may be used to inform hydropower decision making processes at three levels. First, quantifying potential power production at existing dam sites enables comparison among sites and improves understanding of the geographic distribution of Rhode Island hydropower resources. Second, estimates of hydropower potential within each river system aids in assessing the basin-wide impact of hydropower within watersheds. Finally, an estimate of total hydropower potential at the statewide level allows policy makers to forecast the role that hydropower can play in helping Rhode Island fulfill its obligation under the Renewable Energy Standard (RES) of obtaining 16% of its energy from renewable sources by 2019. This section offers a summary of the RESP hydropower assessment; the complete analysis is contained in RESP Volume 2.

2.1 RESP Resource Assessment Methodology

Section Summary

- Rhode Island rivers contain 742 dams; many are no longer used for their original purposes. The RESP hydropower resource assessment set out to quantify estimated hydropower output at these dams.
- The key inputs to estimating hydropower potential are hydraulic head (the vertical distance that water behind a dam travels before passing through the turbine) and flow volume (the quantity of water discharged per unit time).
- The RESP model relied on published dam heights as a proxy for hydraulic head and estimated flow volume for each dam site using basin relief and drainage area data.
- The RESP flow volume model was validated using empirical flow volume data obtained at 37 USGS stream gages around the state over the last 17-34 years.
- RESP researchers used hydraulic head and flow volume estimates to predict power production potential at the 57 largest existing dam sites in the state.

The power output of a hydroelectric system at a given point in time is determined by two physical characteristics of a dam site: flow volume and hydraulic head. Flow volume refers to quantity of water discharged per unit time. All else being equal, greater quantities of water flowing through a turbine produce greater amounts of electrical power. Flow volume varies seasonally and is shaped by precipitation patterns and other factors; therefore, a single number may not capture the range of flow values found at a site. Instead, flow is sometimes represented by a flow duration curve (FDC) (Ch. 3 Figure 2). An FDC is based on a frequency distribution showing the percentage of time that flow volume exceeds each possible flow volume value. The time percentage corresponding to each possible flow volume value is called the exceedance probability. The downward slope of an FDC reflects the fact that as the curve approaches higher flow values, the probability of a river exceeding these values decreases. Put another way, extremely high discharge volumes are rare, whereas at least a small amount of flow occurs in a river nearly all of the time.



Ch. 3 Figure 2. Example Flow Duration Curve

The other physical characteristic affecting hydropower potential is hydraulic head. Hydraulic head is a measurement describing the vertical distance that water travels before passing through a turbine. It can be measured in units of distance (feet or meters) or units of pressure. All else being equal, water passing through a turbine from a higher elevation produces more energy. Generally, hydroelectric power is not feasible where hydraulic head is less than 2 ft (0.61 meters; NREL 2001).

Two parallel efforts assessed hydropower resources in Rhode Island in 2012. The RESP hydropower resource assessment was one of these efforts, and an RIDEM Office of Water Resources assessment of Rhode Island hydropower resources (RIDEM 2012) was the second. The RIDEM analysis provided a useful first glance at potential hydropower resources in the state, while the RESP fine-tuned RIDEM's resource potential calculations to further constrain those estimates. RIDEM's preliminary quantification of power production potential at each existing dam site used published information on dam height data as a proxy for hydraulic head and used a statewide median flow value of 2 ft^3 per second per $mile^2$ of drainage area as a proxy for flow. RIDEM evaluated the 326 largest dams in Rhode Island and determined that these dams represent a total of 15-20 MW of hydropower potential. The RIDEM assessment estimated that half of the hydropower potential in the state (approximately 8 MW) is associated with 9 dams on the Blackstone River, and an additional 3 MW of potential is associated with 19 dams on the Pawtuxet (RIDEM 2012).

Like the RIDEM analysis, the RESP relied on published dam heights to estimate hydraulic head at each site analyzed. But instead of using a single mean flow value to analyze sites across the state, the RESP developed site-specific flow values using basin relief and drainage area information. Basin relief is the difference between the highest and the lowest points in a drainage basin, and is an indicator of the slope of the basin. Drainage area refers to the entire cumulative area drained by a dam. The RESP method is not as accurate as taking long-term field measurements of flow at each dam site, but it is more precise than using a mean statewide flow value for each dam site, and represents the best state-level estimate to date of hydropower capacity on Rhode Island rivers.

In order to quantify power potential at each dam in the state, RESP researchers began by developing a regional regression model to estimate flow data at dam locations. The model predicts flow at dam sites by describing a state-wide relationship between basin relief, drainage area, and daily flow values. RESP researchers supplied data for the model from several sources of information, including GIS software and the U.S. Geological Survey (USGS) National Water Information System.

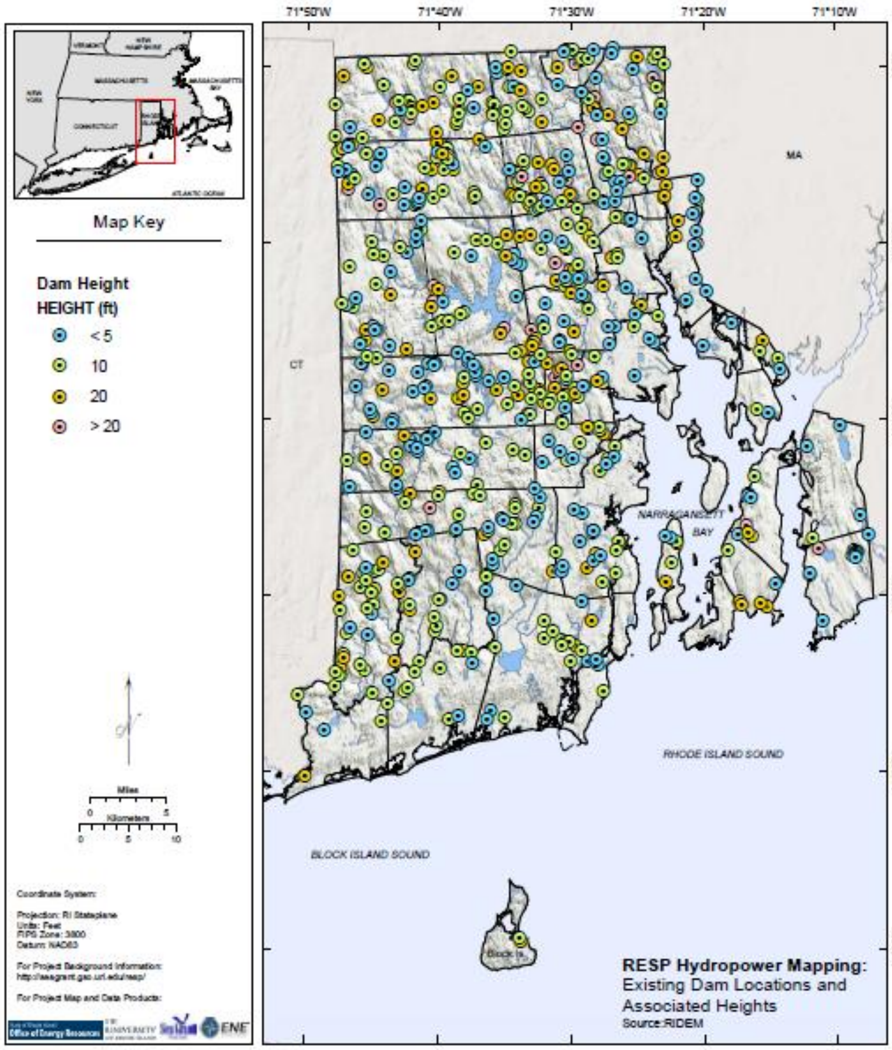
The first step towards developing the model involved gathering actual daily flow values measured by 37 USGS stream gages installed at rivers around Rhode Island. Each gage represents between 17 and 34 years of historical stream flow data. RESP researchers used the calculated mean and standard deviation of daily flow data from each gage together with each site's corresponding drainage area and basin relief values to generate the regional regression equation. The resulting model relates flow parameters (mean and standard deviation of flow) to basin and topographical parameters (drainage area and basin relief), allowing RESP researchers to generate a synthetic flow duration curve for any dam site in Rhode Island, given information about that dam's drainage area and basin relief.

In order to evaluate the precision of the model, RESP researchers compared outputs from the regional regression equation to empirical flow duration curves developed using historical flow records from sites where gages were located at an actual dam. By comparing synthetic flow values with recorded data from USGS gages, RESP researchers were able to validate the regional regression model that they developed to describe the relationship between basin relief, drainage area, and daily flow values. No statistically significant difference was found between the modeled synthetic flow duration curves and the instrumental flow measurements recorded by stream gages.

After establishing the validity of the model, RESP researchers calculated flow value predictions for each of the 57 largest dam sites in Rhode Island based on GIS-measured and published basin relief and drainage area data. The 57 sites selected are located within the fourteen major drainage basins in Rhode Island. Selected sites represent a range of stages in the development process: seven sites already contain hydroelectric facilities licensed by FERC; six are sites presently undergoing the FERC licensing process to be developed for hydropower and have been issued a preliminary permit to that end; and the remaining 44 are undeveloped and are not currently undergoing any plans for development.

Just as in the RIDEM analysis, RESP researchers used dam height measurements from the master dam spreadsheet maintained by the RIDEM Office of Water Resources as a proxy for hydraulic head (see Appendix B of the Hydropower Technical Report in Volume 2 of this Report) (Ch. 3 Figure 3). Data in RIDEM spreadsheet derive from inspection reports carried out under RIDEM's Dam Safety Program and from information submitted by dam owners. Despite known inaccuracies in some of the dam height data contained in this spreadsheet (CLF 2010; Essex Partnership 2010), the data is adequate for state-level analyses such as that performed by the RESP. However, field measurements should be conducted in the future to improve the accuracy of dam height data.

After obtaining dam height data, RESP researchers predicted the power capacity of a hypothetical hydropower facility at each dam site, using a formula incorporating flow rates, hydraulic head (estimated by dam height), and a water-to-wire efficiency value of 0.9. Three different power potential estimates were generated for each site to model a range of scenarios: predicted capacity at 70% exceedance, predicted average capacity, and predicted nameplate capacity (the rated capacity of a plant, reflecting the maximum capacity at which that plant can operate).



Ch. 3 Figure 3. Rhode Island Dams and Dam Heights.

2.2 RESP Resource Assessment Results

SECTION SUMMARY

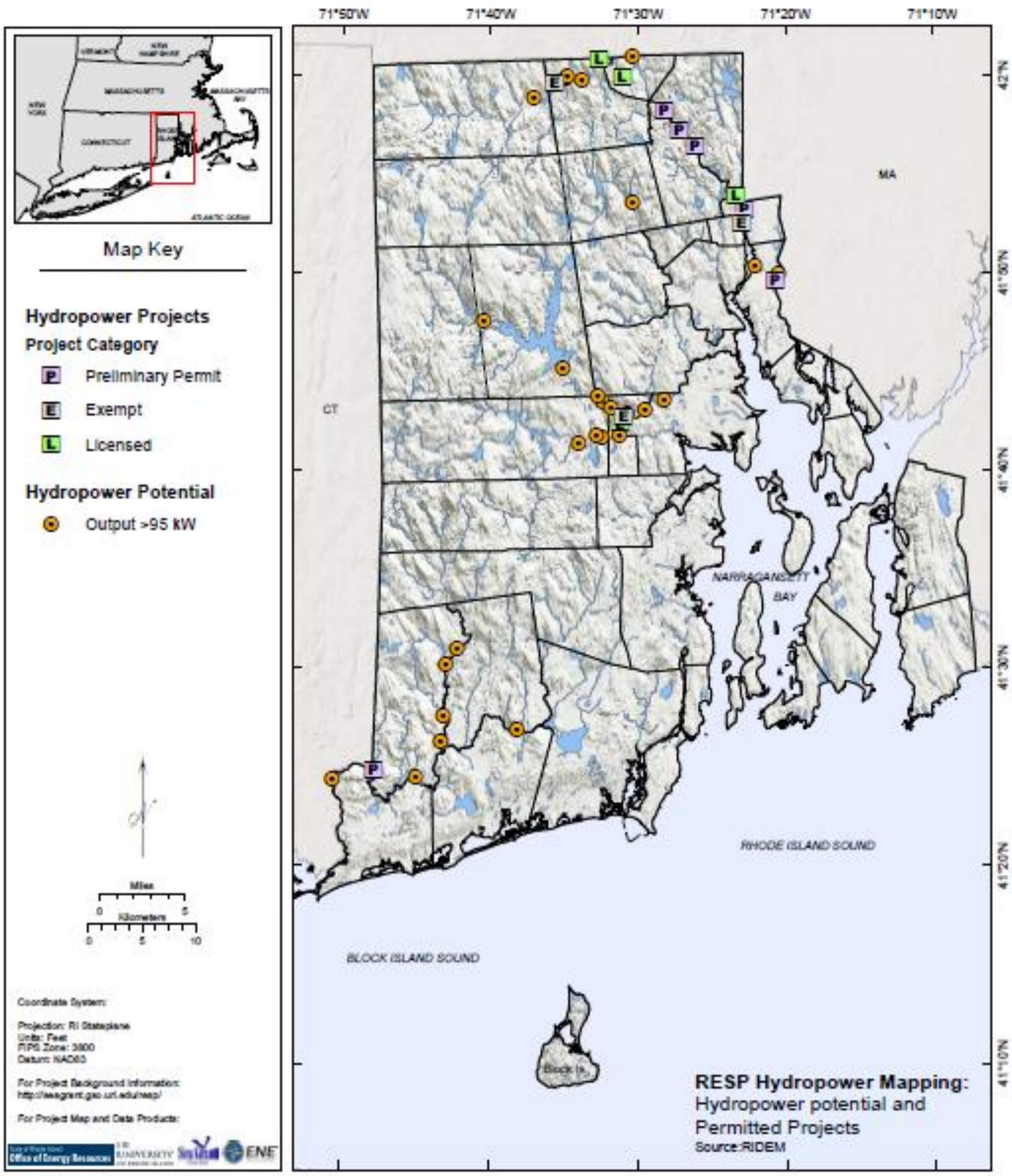
- RESP researchers estimate that Rhode Island's existing dam sites have a collective potential to generate approximately 21 MW in nameplate capacity and 15 MW in average capacity.
- The Blackstone River is estimated to represent almost 13 MW in potential nameplate capacity; the Pawtuxet River is estimated to represent approximately 5 MW in potential nameplate capacity; and the Wood-Pawcatuck, Ten Mile, and Woonasquatucket rivers are estimated to represent 2.75 MW of collective potential nameplate capacity.
- The RESP estimated that 6.7 MW in nameplate capacity are available at sites already developed for hydropower, 4.8 MW are available at sites currently proposed for hydropower, and 9.2 MW are available at 44 undeveloped sites with no immediate plans for development.

- The RESP analysis represents the most refined calculation of hydropower potential in Rhode Island to date.

Resulting capacity estimates for each dam site range from a few dozen kW to over 1 MW per site (See Hydropower Technical Report in Volume 2 of this Report). Collectively, the 57 sites analyzed present a total approximate nameplate capacity of 21 MW, and an approximate average capacity of 15 MW. This figure is in line with previous estimates provided by the RIDEM analysis and Idaho National Laboratory studies. Based on their analysis of 326 dams, RIDEM estimated a total capacity of 15-20 MW. A 1995 Idaho National Laboratory analysis, based on 30 undeveloped dams in Rhode Island, estimated their collective potential capacity at between 11.5-13.5 MW (USDOE 1995); it should be noted that this figure does not include dams already developed for hydropower in 1995. Although the RESP analysis did not provide any surprises in terms of the overall hydropower capacity potential present in Rhode Island, it reduces the coarseness of available flow data by using stream- and site-specific flow estimates rather than a blanket statewide estimate.

The RESP hydropower resource analysis shows that while much of the available capacity in Rhode Island is already being harnessed by hydropower facilities, much has yet to be developed (Ch. 3 Figure 4). According to RESP calculations, developed sites possessing FERC licenses or exemptions represent 6.66 MW of capacity. Undeveloped sites with a preliminary FERC permit represent 4.82 MW of capacity. Undeveloped sites with no immediate plans for development represent 9.23 MW of capacity. It is worth noting that although undeveloped dams represent a significant proportion of the total potential (9.23 MW), this category contains the largest number of dams (44), reflecting the fact that the dams in this category are far more limited in their potential capacity on a per-site basis than those in the developed and pre-permit stages.

The RESP resource assessment also confirmed previous findings that the vast majority of Rhode Island's hydropower resources are concentrated primarily in two watersheds: the Blackstone and the Pawtuxet. The Blackstone contains almost 13 MW of potential nameplate capacity; the Pawtuxet contains about 5 MW of potential nameplate capacity. Dams evaluated in the remaining watersheds (Wood-Pawcatuck, Ten Mile, and Woonasquatucket) account for approximately 2.75 MW of potential nameplate capacity.



Ch. 3 Figure 4. Existing and Proposed Hydropower Projects and Hydropower Potential (RIDEM power potential calculations).

3. Hydropower Development Constraints and Opportunities

Existing dams in Rhode Island have become naturalized elements of the fluvial ecosystems of the state and are a visible part of the state's historic, cultural, and economic fabric. According to the Governor's Task Force on Dam Safety and Maintenance (2011), "[t]he waterbodies created by many of these dams provide great benefits to the citizens of the State: drinking water, flood management, recreational waterbodies, and scenic beauty. These benefits increase the quality of life for many Rhode Islanders. Humans aren't the only beneficiaries. Many dams are surrounded upstream and downstream by valuable wetlands that sustain a wide variety of animal and plant species (11)."

Retrofitting these existing dams for the purpose of hydroelectric generation challenges developers and local authorities to balance the benefits of renewable energy against any undue harm that might result to the surrounding environment, culture, and economy. The RESP evaluated possible adverse impacts of hydropower development through a literature search, extensive collaboration with RIDEM, and a targeted stakeholder process that included two all-day workshops with dam and river experts (see Chapter 5 of this document for a complete description of the RESP hydropower stakeholder process). The next section provides an overview of anticipated impacts, both negative and positive, of renovating existing dams to produce hydroelectric power.

3.1 Environmental Siting Considerations

Section Summary

- Existing dams can have both positive and negative effects on river ecology. Understanding these effects is a first step to predicting the ecological impacts of future hydroelectric facilities sited on existing dams.
- Positive effects of dams on river ecosystems can include maintenance of valuable wetlands, flood control services, and containment of buried contaminants found in sediments upstream. Initiation of hydropower activity on existing dams may undermine these positive functions.
- Negative effects of dams on river ecosystems can include obstruction of fish passage, interruption of streamflow, and impacts on dissolved oxygen and temperature. Initiation of hydropower activity on existing dams has the potential to reinforce these negative effects unless mechanisms are put in place to counteract them.
- Restoration of fish passage at existing dam sites is a high priority in Rhode Island. Care must be taken to assure that new hydropower facilities do not undermine fish passage restoration efforts currently underway. It may be possible to capitalize on future development of hydropower in the state as a way to further the goal of restoring fish passage to Rhode Island rivers.
- Development of hydropower may cause fluctuations in streamflow, particularly when multiple facilities are located along the same river. Decreased streamflow can lead to stranding of aquatic organisms in isolated pools, and must be avoided

through integrated management and careful observation of water flow at hydroelectric plants.

- Development of hydropower may cause declines in dissolved oxygen, which is critical for respiration of aquatic organisms. Aeration mechanisms can be put in place to counteract this potential effect.
- The environmental effects of a hydropower on a river ecosystem are a function of the unique biological and physical conditions present within each river system, and can usually be controlled through hydroelectric operating plans customized to the specific environmental conditions present at each dam site.

By obstructing river flow, dams inevitably affect many aspects river ecology. For instance, dams can have complex effects on oxygen levels, can negatively affect stream flow, and can hinder the ability of fish to move up- and downstream. Perhaps paradoxically, dams on Rhode Island rivers have also become integral elements of river ecosystems, sustaining valuable wetlands and performing necessary flood control. Understanding the dichotomous role of existing dams in river ecosystems is a vital first step to predicting the environmental impacts of retrofitting these dams to generate hydroelectric power.

3.1.1 Fish Passage

Dams have a marked impact on the ability of fish to move through rivers, particularly when fish are swimming in an upstream direction. This is a serious concern for diadromous fish, which spend part of their lives in freshwater rivers and part of their lives in the ocean. Diadromous fish in Rhode Island include those with anadromous life histories (i.e., those that are born and spawn in freshwater rivers and spend most of their adult lives at sea) and catadromous life histories (i.e., those that are born and spawn in the ocean and spend most of their adult lives in freshwater). Anadromous fish with a history of spawning in Rhode Island rivers include American shad, alewives, blueback herring, and Atlantic salmon (R.I. Habitat Restoration Portal 2012). These species return from the ocean to their native streams to spawn (Save the Bay 2012). The only catadromous fish to frequent Rhode Island rivers is the American eel, which spawns in the Sargasso Sea (R.I. Habitat Restoration Portal 2012).

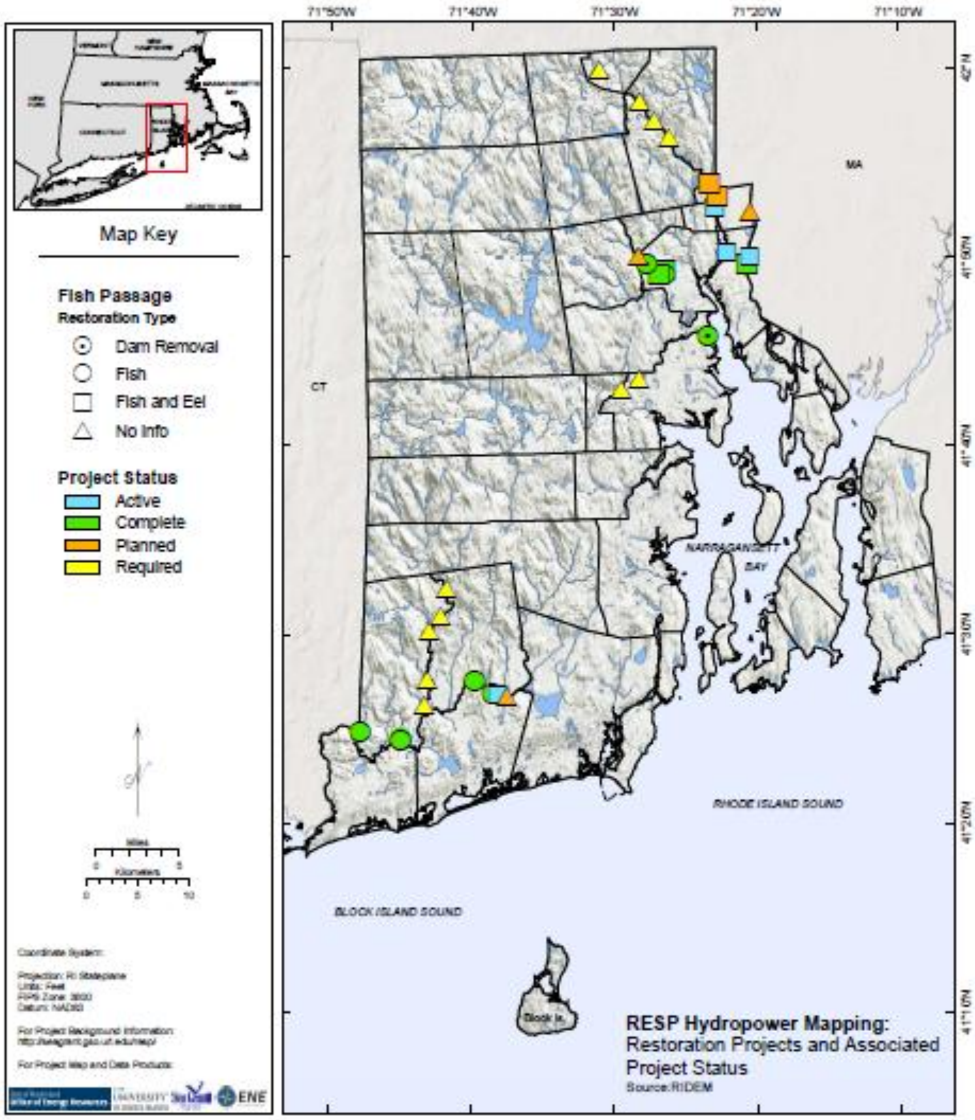
Dams and hydropower have been identified as the top threat to upstream and downstream migration of diadromous fish on the East Coast (ASMFC 2009). Dams prevent anadromous fish from reaching the upstream spawning and nursery habitats that they require in order to reproduce, and prevent catadromous fish from reaching valuable upstream rearing habitat (RIDEM 2012). Diadromous fish populations have declined since the 19th century, primarily as a result of obstruction of rivers by dams (Rhode Island Habitat Restoration Portal 2012). Atlantic salmon has been extirpated as a breeding species in much of its range, including Rhode Island (although state and federal resources have been spent trying to reintroduce salmon into the Wood-Pawcatuck river system) (Save the Bay 2012). Shad, alewives, and blueback herring are still found in some rivers in Rhode Island, but are now protected through moratoriums on harvest of these species in rivers (RIDEM 2005; RIDEM 2006). River herring are an important link in estuarine food webs, and there is consideration of designating them under the Endangered Species Act. As an indication of the impact of dams on these fish species, Save the Bay (2012) maintains that fish can reach spawning grounds in only 18 of 45 historic runs in the Narragansett Bay watershed. In addition, evidence suggests that dams can also obstruct movement of resident stream organisms (RIDEM 2012). For example, dams can adversely affect freshwater mussels, which require river connectivity because their larvae migrate via parasitism on mobile animals such as amphibians and fish (RIDEM 2012).

Restoration of fish passage to Rhode Island rivers and streams is now a priority for many organizations, including RIDEM, the Narragansett Bay Estuary Program, the National Coastal Fish Habitat Partnerships, NOAA’s National Marine Fisheries Service, the Natural Resources Conservation Service, Save the Bay, and many watershed organizations. RIDEM’s 2002 Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams lays out a roadmap for improving fish passage by identifying least-cost options for removing dams or constructing fish ladders (RIDEM 2002). In addition, the RIDEM Division of Fish and Wildlife maintains a prioritized list of actions, including fishway restoration, which the state plans to perform in order to improve habitat for American shad and river herring as part of the Division’s USFWS-supported Restoration and Establishment of Sea Run Fisheries project.

Restoration of fish passage to a river currently obstructed by a dam can be accomplished in two ways: dam removal or installation of fish ladders. From the perspective of fish mobility, the preferred solution is to remove the dam entirely. However, dam removal may be expensive (although generally less so than fish ladder construction), can degrade water quality via the release of contaminated sediments, and in some cases, compromise flood control structures, drinking water reservoirs, or cultural assets. In cases where dam removal is impractical or undesirable, construction of fish ladders may be a more feasible solution (though some evidence suggests fish ladder construction is generally more expensive than dam removal). Fish ladders are ramps built alongside a dam to provide a means for fish to gain upstream access past the dam. Several types of fish ladder have been developed, including steep-pass, denil, and pool-and-weir ladders. Each is suitable for a particular species, stream size, or project budget (Rhode Island Habitat Restoration Portal 2012).

Despite these generalities, there is no single template for successful fish passage restoration, and each dam site requiring fish passage restoration holds its own intricacies and challenges. Restoration design that may prove successful at one location may not deliver desired fish passage results in another. Moreover, approaches to defining the goals and measuring the success of fish passage restoration are evolving. Continuing studies of the effects of dam removal and fish ladders are vital to understanding the complex parameters affecting fishway obstruction and improving success rates of fish passage restoration.

When contemplating installation of new hydroelectric facilities on existing dams in Rhode Island, it is important to take into account fishway restoration projects that may be completed or are underway on dams in the state (RIDEM 2012). RIDEM and others have made significant progress towards restoring fish passage to the Ten Mile, Blackstone, Pawcatuck, Pawtuxet, and Woonasquatucket Rivers (Ch. 3 Figure 5). To protect these investments, RIDEM has declared its intent to intervene in all FERC proceedings regarding proposals to install hydropower on dams that have already been targeted in fishway restoration projects, adding that "past expenditures of public funds for fisheries improvements investments should not be degraded by efforts to develop the river for renewable energy (RIDEM 2012: 8)." With careful planning and coordination among appropriate stakeholders, however, it may be possible to reconcile the colocation of hydropower with fish passage construction in a mutually beneficial fashion. Because no existing hydroelectric facilities operating in Rhode Island currently have fishways, data is lacking on the state-specific impacts of hydropower on fish passage (Edwards, personal communication).



Ch. 3 Figure 5. Fish Passage Restoration in Rhode Island

Hydroelectric additions to existing dams can interact and/or conflict with fish restoration projects in several ways. First, the adaptive reuse of an existing dam for hydropower is clearly incompatible with dam removal, which is the preferred option for addressing fishway obstruction (RIDEM 2012). Second, if a hydropower tailrace (i.e., the channel where water is carried away from a turbine) is placed too close to a fish ladder, the fast-flowing water can confuse fish as they search for a way to ascend, causing them to swim towards the turbine instead of towards a ladder (RIDEM 2012). Additionally, hydroelectric facilities can kill fish through entrainment or impingement of fish on screens or trash racks and by enabling fish to swim up draft tubes (Stillwater Sciences, Confluence Research and Consulting, and Heritage Research Associates, Inc. 2006).

At the same time, constructive reuse of dams that have long lain idle may also present opportunities to improve fish passage on Rhode Island rivers. Since conversion of existing dams into hydroelectric facilities at times requires an overhaul of outdated, unsafe, or ecologically detrimental dam structures, it may afford an occasion to introduce fish passage structures into dams where they have not yet been installed. Where public funds for fish restoration are lacking, financing for new hydroelectric facilities may present an opportunity to leverage private monies for restoring fish passage.

3.1.2 Water Quality

Existing dams have become an established part of the flow regime in Rhode Island rivers. As such, they play a role in regulating water quality. Existing dams can shape several aspects of water quality in a river, including streamflow, dissolved oxygen, temperature, sediments, and wetlands. Just as existing dams may affect these dimensions of water quality, so too can alteration of existing dams to accommodate hydropower facilities. However, the nature of the resulting impact is not necessarily the same in both cases.

Streamflow Dams affect the speed, timing, and volume of water flow in a river. These characteristics are important factors shaping and supporting fluvial ecosystems. When dams delay the flow of water, they can lead to decreased water levels downstream. When this occurs, fish can become stranded in deeper pools of the river, unable to move in an up- or down-stream direction (Stillwater Sciences, Confluence Research and Consulting, and Heritage Research Associates, Inc. 2006). In cases where widespread stranding affects spawning fish or larvae, it can have population-wide impacts. Drops in streamflow can also affect the diversity of invertebrate communities and cause desiccation of amphibian egg masses (Stillwater Sciences, Confluence Research and Consulting, and Heritage Research Associates, Inc. 2006).

Since run-of-the-river operation is the norm at Rhode Island hydropower facilities, current and future hydroelectric facilities in the state are expected to have a minor effect on streamflow compared with large impoundment facilities of the type found in the western U.S. (RIDEM 2012). However, despite their relatively benign effects on streamflow, run-of-the-river dams can produce short-term fluctuations in streamflow, and in special circumstances these fluctuations can become significant. For instance, facilities requiring construction of a bypass reach to increase hydraulic head have the effect of decreasing flow volume within the main branch of the river between bypass intake and bypass discharge, potentially causing under-wetting or dryness (RIDEM 2012).

In addition, the operation of multiple hydropower facilities on a single river can cause a cumulative effect on streamflow, especially when operated by two or more different owners without a coordinated strategy for communication. Cumulative impacts are most likely to occur during periods of low flow, when one poorly operating plant holds back water upstream to increase hydraulic head, leading a downstream plant to follow suit in an effort to compensate for the reduced water flow. Tactics such as these effectively amplify the original interruption in streamflow, resulting in a more significant alteration of flow than would be caused by each plant alone (RIDEM 2012).

Dissolved oxygen Aquatic animal life requires dissolved oxygen for respiration. Dams and hydroelectric equipment can have both additive and subtractive effects on dissolved oxygen in a river. By allowing water to churn and mix with the air as it falls over the top of the dam face, dams bring about an oxygen addition to river water. Conversely, dams can subtract dissolved oxygen from a river when they impound water within reservoirs; impoundment can cause water to become stratified throughout the water column and anoxic at depth. The net effect of a dam on dissolved oxygen depends on a combination of these factors. Hydroelectric turbines, in contrast, consistently represent a removal of dissolved oxygen. Unlike water flowing over a dam, water flowing through a turbine is not mixed with air and does not gain oxygen as it travels downstream. Moreover, if water is drawn through a turbine from the bottom of a stratified reservoir, it may not contain enough dissolved oxygen to support life downstream; however, this effect is more likely to occur in large-scale hydropower facilities than in small dam settings like those in Rhode Island.

While all hydroelectric turbines represent an oxygen removal from a river system, the magnitude and implications of this impact vary and are determined by multiple factors. The potential of dams to cause adverse impacts on dissolved oxygen levels is a function of the biological and physical conditions within each river system. These include temperature, nutrient levels, biological oxygen demand, and presence of waste treatment plants on a river. As a result, assessing how a hydropower facility will affect a river system's dissolved oxygen content requires a nuanced understanding of the multiple sources and sinks governing dissolved oxygen levels within the river. Negative impacts on dissolved oxygen levels resulting from a hydropower facility can be mitigated through mechanical aeration of the water exiting the facility or through shutdown during periods when minimum required dissolved oxygen levels cannot be met (RIDEM 2012).

Temperature By altering natural water levels within a river, dams can cause changes in water temperature with possible repercussions for aquatic life. Dam ponds tend to be stratified, with the water at the bottom colder than the water at the top. If hydroelectric equipment installed on an existing dam draws water from the bottom of the dam pond, it can introduce water to the downstream reach that is colder than the temperatures that the system would otherwise experience. If flashboards are installed on top of a dam to increase hydraulic head, they may warm surface water by retaining it for extended periods of time, causing water within the pond, as well as water flowing over the top of a dam, to be warmer relative to natural conditions (RIDEM 2012). Some existing species may be ill-adapted to such altered temperature regimes, while others, such as nuisance algal blooms, may prosper under such changed conditions.

Understanding the effects of hydropower on water temperatures and the consequent ramifications for aquatic life is key to siting and constructing hydropower facilities in a way that avoids harm to river ecosystems.

Sediments Because of the historical origins of many of Rhode Island's dams as sources of mechanical power for industrial mills, sediments collected behind dams sometimes contain harmful chemicals, including copper and lead (RIDEM 2012). Poor sediment quality is known to exist on the Blackstone, Pawtuxet, Ten Mile, and Woonasquatucket Rivers (RIDEM 2012). Data on sediments behind dams is currently limited, and hydropower developers planning to alter existing dams in a way that might cause dam pond sediments to reenter the water column may be required to evaluate sediments and plan for proper disposal (RIDEM 2012).

3.1.3 Climate Change

Trends associated with a changing climate may increase the uncertainty associated with long term predictions of power production at a site. At a global level, climate change is expected to result in increased precipitation (IPCC 2007), which can be expected to result in greater streamflow, thereby improving the generation of energy from hydropower (Harrison and Whittington 2002). At the same time, higher temperatures are expected to lead to increased rates of evapotranspiration, which can be expected to decrease the streamflow available to generate hydropower (Harrison and Whittington 2002). In addition, in some parts of the world, increased storminess associated with climate change may increase the occurrence of peak streamflow events (Lenderink and Van Meijgarrd 2008). All impacts of climate change are regionally specific, and further research at the regional level is necessary to elucidate effects on river flow in Rhode Island.

Preliminary research performed in New England suggests that timing of peak river flows is changing due to alteration of snow patterns. Historical records indicate earlier snowmelt runoff (Burns et al. 2007, Hodgkins et al 2003), earlier peak river flows (Hodgkins et al 2003), and a decreasing ratio of snow to total winter precipitation (Huntington et al., 2004). Model simulations indicate that these trends are expected to continue (Hayhoe et al. 2006). In addition, simulations suggest that winter precipitation may increase by 10-15%, while summer precipitation may decrease or remain the same (Hayhoe et al. 2006). These findings may have important implications for the flow duration curves of rivers used for hydropower.

The magnitude and direction of changes in precipitation, evapotranspiration, and peak streamflow events due to climate change are expected to vary widely and unevenly across the globe. While the precise effects of climate change on the New England region differ from global trends, one thing is clear: rapid climate change may undermine the accuracy of current estimates of hydropower resource availability (Whittington et al. 1998).

3.2 Cultural, Historical, and Public Safety Siting Considerations

SECTION SUMMARY

- Many of Rhode Island's dams are celebrated as relics from the past. Hydropower development at these dams must be carried out in a way that respects and maintains their historical value.
- Dam sites and their environs may be subject to one or more forms of legal protection intended to safeguard their historic or cultural value. These include the National Register of Historic Places, local historic district ordinances, and regulations pertaining to the John H. Chafee Blackstone River Valley National Heritage Corridor.
- Hydropower facilities on existing dams have the potential to alter the recreational value of Rhode Island rivers by obstructing river bank access points, decreasing water depths needed to support paddling activity, impeding fishing activities in the immediate vicinity of the dam, and adversely affecting fish populations pursued by freshwater anglers.
- Input from the public and recreational users is crucial to assuring that new hydropower usage of existing dams does not conflict with established recreational uses of Rhode Island's waterways.
- Dam failure is on the rise across the nation. According to RIDEM, ninety-seven of Rhode Island's dams have the potential to cause injury, property damage, and loss of life in the event of failure.
- Dam safety must be carefully evaluated and addressed prior to any hydropower development. In addition, hydropower development may provide an avenue to leverage new funding for safety improvements to existing dams.

Dams play a significant and yet often unnoticed role in day-to-day life in Rhode Island. By providing ponds to recreate in, historic vistas to learn from, water to drink, and flood control, dams offer multiple public services. They can also represent public threats, especially if they become derelict or experience structural failure. Retrofitting of existing dams for hydropower raises many questions about how these services and hazards should be addressed during dam modification. In fact, these considerations may determine whether addition of hydropower is even appropriate in the first place. The RESP relied on a literature review and a stakeholder discussion process to shed some light on these considerations.

3.2.1 Historical and Cultural Considerations

Many of Rhode Island's dams played a vital role in the development of the state's culture and economy. Built to turn grain mills during the colonial days or to power factory machines during the industrial era, these dams are rare artifacts from bygone eras that provide visible reminders of the past.

Retrofitting existing historic dams for hydroelectric generation is likely to alter the appearance of these dams. Whether this change detracts from, or adds to, the historical value of a dam is both a subjective and site-specific matter. On one hand, modern hydropower equipment installed on an existing dam may change or obscure the visual aspect of a dam, conflicting with its historic appearance. On the other hand, the use of an old mill dam for hydroelectric generation may arguably be valued as a restorative twist on its former hydro-mechanical use. Citizen groups in other states have attempted to retrofit old dams for hydropower as a strategy to preserve them from deterioration or removal (Serreze 2010; Sharpe 2008).

In addition to altering the historic integrity of an old dam itself, retrofitting historic dams for hydropower purposes may indirectly alter the visual historic value of sites nearby, by introducing new and modern equipment into the panorama. For this reason, the historical significance of a dam may require evaluation within the broader historical and cultural context of the landscape in which it is situated (McClain *et al.* 2008).

Dams in Rhode Island and their environs may be subject to one or more forms of legal protection intended to safeguard their historic or cultural value (Ch. 3 Figure 6). Each of the following legal designations applies to certain categories of dams or rivers.

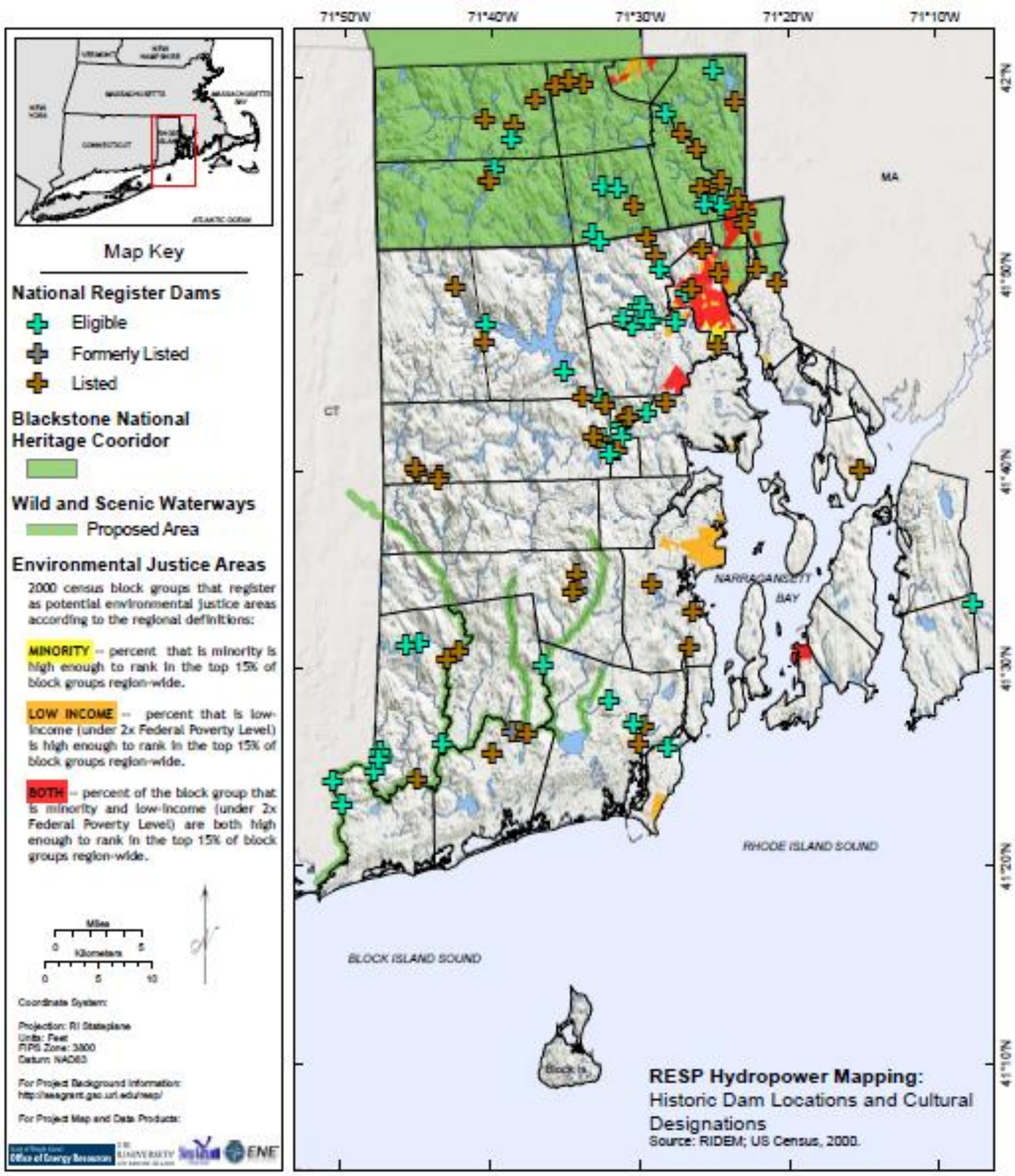
National Register of Historic Places The National Register of Historic Places catalogs and protects properties deemed to possess particular historical significance. Properties may be listed in the Register for one or more of the following reasons: they are associated with important events from the past; they are associated with an important historical person; they possess historically significant design characteristics, methods of construction, or architectural uniqueness; and/or they provide new information about our past. When a dam or its immediate surroundings are listed or eligible for listing on the National Register of Historic Places, the dam or adjacent site is subject to the protections of the National Historic Preservation Act (16 U.S.C. 470 et seq.) of 1966, which requires that all federally permitted activities, including those licensed by FERC, submit to a consultation process involving the State Historic Preservation Officer, Tribal Historic Preservation Officer, and stakeholders. More information on the National Historic Preservation Act is available in Section 4.1.1 of this report. The National Register of Historic Places lists 61 of Rhode Island's dams as part of a historic property, and another 47 are eligible for listing (SHPO, personal communication).

Historic Districts Local historic districts are special zoning areas created through municipal ordinances to help protect historic buildings and preserve the historic character of sections of a community. Bristol, Cranston, Cumberland, East Greenwich, East Providence, Glocester, Hopkinton, New Shoreham, Newport, North Kingstown, North Providence, North Smithfield, Pawtucket, Providence, South Kingstown, and Warwick have all passed ordinances creating historic districts. Historic zoning was enabled by the General Assembly's 1959 historic district zoning legislation, which also authorizes cities and towns to create municipal commissions to review proposed changes for historic sites and areas. In addition, all Rhode Island municipalities have comprehensive plans that include provisions for preservation of historic resources. Alteration of dams located within a historic district will likely require approval by the town's historic commission, and may be subject to conditions intended to maintain the historic integrity of the area.

John H. Chafee Blackstone River Valley National Heritage Corridor The John H. Chafee Blackstone River Valley National Heritage Corridor is managed by the National Park Service and spans the entire 46-mile-long Blackstone River Valley, from Worcester, MA to Pawtucket, RI. Congress established the Corridor in 1986 for the purposes of "preserving and interpreting for the educational and inspirational benefit of present and future generations the unique and significant contributions to our national heritage of certain historic and cultural lands, waterways and structures within the Blackstone Valley (P.L. 99-647)." The river's historic dams, which supported iron, steel, and textile mills, are a vital heritage component of the Corridor. In fact, the Cultural Heritage and Land Management Plan for the Blackstone River Valley National Heritage Corridor states that much of the historic significance of the corridor derives from the fact that "it represents the first widespread industrial use of water power in the United States (State Planning Council 1990)."

The legislation establishing the Heritage Corridor created a Blackstone River Valley National Heritage Corridor Commission, made up of individuals from the state governments of Massachusetts and Rhode Island, local governments, the National Park Service, and others. The role of the Commission is to assist Federal, State and local authorities in the development and implementation of an integrated resource management plan for the lands and waters encompassed by the National Heritage Corridor. Any federal entity conducting or supporting activities directly affecting the Heritage Corridor must consult with the Commission regarding these activities and, to the extent practicable, conduct or support such activities in a manner that the Commission determines will not have an adverse effect on the Heritage Corridor (P.L. 99-647 § 9). This category includes all FERC-licensed hydropower facilities located on the Blackstone River.

The Heritage Corridor Commission is not a permanent body, and there is no permanent funding for Heritage Corridor preservation and educational activities. In response to this, the National Park Service completed a Special Resource Study of the Blackstone River Valley in July 2011 to determine whether the historical features of the Heritage Corridor make it eligible for inclusion as a unit of the National Park System. In October 2011, a bill was introduced in the federal House and the Senate to change the status of the Heritage Corridor to the Blackstone River Valley Industrial Heritage National Historical Park. If this bill is enacted, the area will achieve the status of a national park, and will require a management plan developed by the National Park Service. This would enhance the area's legal standing, while making it eligible for consistent federal funding.



Ch. 3 Figure 6. Historic and Cultural Hydropower Siting Considerations

3.2.2 Recreational Considerations

Rhode Island's 1,420 miles of rivers are popular destinations for paddling, hiking, swimming, and contemplation. Most are slow moving, scenic, and easy to paddle. Many contain wild freshwater fish, such as native brown trout, largemouth bass, northern pike, and crappie; stocked freshwater fish such as trout and landlocked salmon; and diadromous fish like eels, shad, and river herring. During cold winters, dam ponds may provide access to ice for skating. Rivers and wetlands are popular spots for bird- and wildlife-watching, hiking, and nature appreciation.

Recreation on Rhode Island rivers not only provides cultural value to residents of the state, but represents a valuable component of the state's economy. The Blackstone Valley is a prime example of the economic value of a culturally important river. This area hosts over one million visitors per year (Blackstone Valley Tourism Council), and in 2006, tourism accounted for 4-15% of total employment in each of the nine Blackstone Valley communities (Miyake 2008).

Modification of existing dams for the purpose of installing hydroelectric generating capacity could conceivably alter the recreational value of Rhode Island rivers in several ways. First, the operation of hydroelectric equipment on a dam could interfere with recreational access to the river by making the dam and its impoundment off-limits to recreational activities in the immediate vicinity. Second, new use of hydropower on a dam could potentially decrease streamflow, diminishing the ability of recreational paddlers to use a river, and increasing the need for portages. Third, the operation of hydroelectric equipment could impede fishing activities in the immediate vicinity of the dam, and, if poorly designed, could have adverse effects on fish populations valued by freshwater anglers.

Wild and Scenic Rivers Designation The recreational, cultural, and natural value of the Wood-Pawcatuck River and some of its tributaries may soon receive additional protection from development due to a process underway to consider its eligibility for federal designation as a Wild and Scenic River. Wild and Scenic Rivers are those considered by Congress to have "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values", which warrant that they "shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations (Wild and Scenic Rivers Act; 16 U.S.C. 1271 et seq.)."

The enactment of the Wild and Scenic Rivers Act in 1968 was a direct response to the adverse impacts of dams occurring on many of the nation's rivers: "The Congress declares that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes (U.S.C. 1271 et seq.)." The National Wild and Scenic Rivers System now protects 12,598 miles, or about one quarter of one percent, of U.S. rivers as "wild and scenic". In contrast, about 600,000 miles, or about 17%, of American rivers have been modified from their original state by 75,000 large dams across the country (National Wild and Scenic Rivers System 2012).

The Wood-Pawcatuck Watershed is being considered for designation as a Wild and Scenic River by the Rhode Island and Connecticut Congressional delegations, following the recommendations of the Wood-Pawcatuck Watershed Association, The Nature Conservancy, Save the Bay, and RIDEM. This coalition proposed the designation of 87 sections of the Beaver, Chipuxet, Queen, Pawcatuck, and Wood Rivers as Wild and Scenic, citing recreational, historic, botanic, geologic, and wildlife conservation rationales. If the bill passes, the National Park Service will fund a three-year study to assess the watershed's Outstanding Remarkable Value (ORV) and assemble a management plan for the river using stakeholder input from neighboring towns. If, at the end of the study, the National Park Service recommends designation of these sections of the watershed as Wild and Scenic, the Rhode Island and Connecticut Congressional delegations must present a bill asking Congress to support designation. If these 87 river sections receive Wild and Scenic designation, preservation of ORV will become a critical factor for all river-related projects that require federal permits. Under Wild and Scenic status, no new dams or hydroelectric development would be allowed within these sections of the watershed.

3.2.3 Dam Safety

Dam safety is a concern not only in Rhode Island but throughout the nation. Between 1998 and 2008, the number of recorded deficient dams throughout the U.S. rose by 137%, and the rate of incidence of newly occurring deficiencies currently lags behind the pace of dam repairs (Association of State Dam Safety Officials 2012). Since most of Rhode Island's dams are over a century old, dam integrity may be an issue of concern affecting the development of new hydropower facilities.

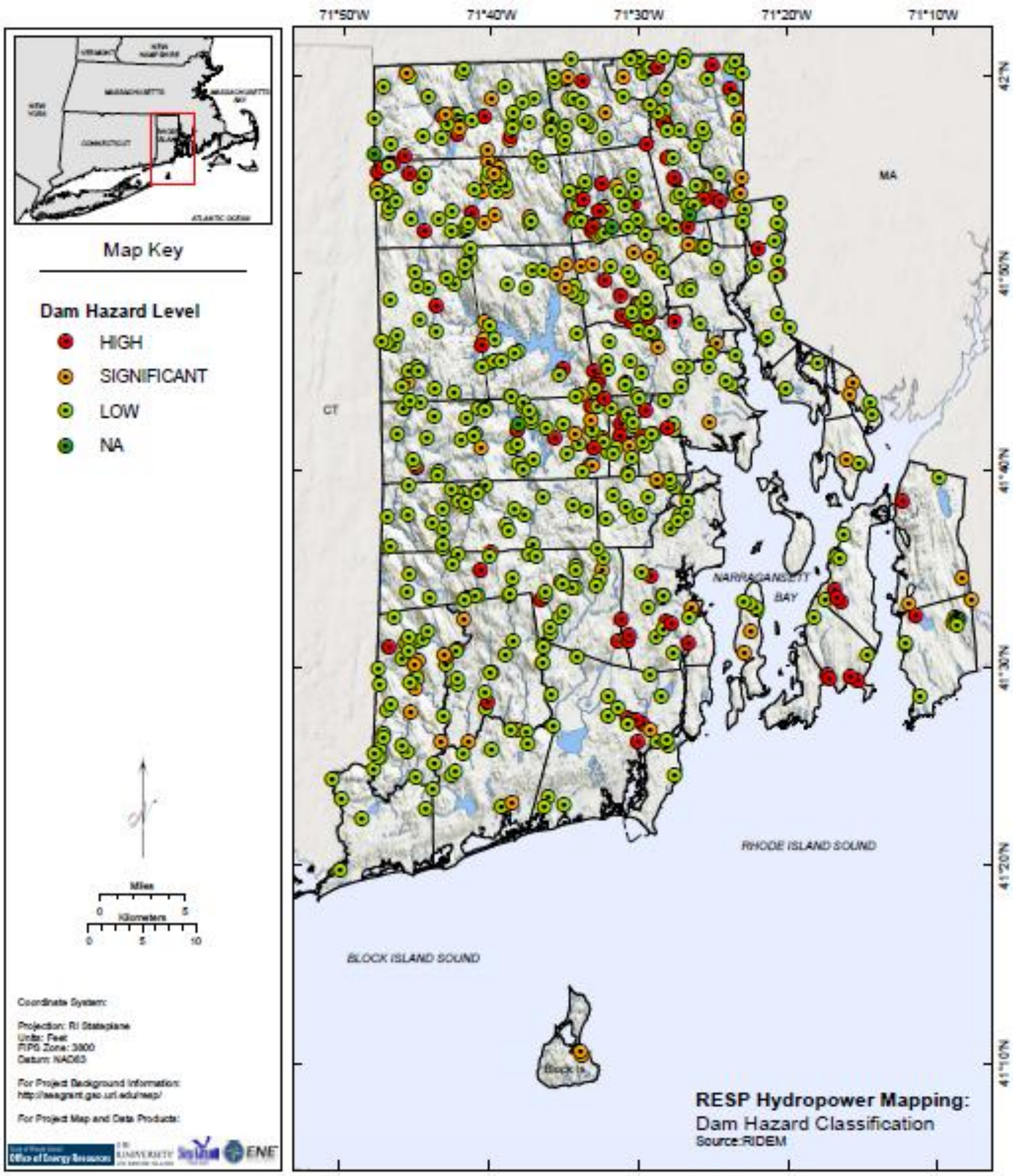
Dam failure can occur in several ways. At a national level, 34% of all U.S. dam failures are related to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest. Another 20% of failures are caused by piping (i.e., internal erosion resulting from seepage around hydraulic structures such as pipes and spillways), burrowing by animals around the roots of woody vegetation and cracking of dams, dam appurtenances, and dam foundations. Remaining causes of failure include structural failure of the materials used in dam construction and inadequate maintenance practices (Association of State Dam Safety Officials 2012).

Dam safety is both a public safety and an environmental concern. Catastrophic dam failure can lead to injury, loss of life, and property damage through flash flooding. If sediments behind a failed dam contain contaminants, structural failure can cause downstream contamination and lead to negative environmental effects. In addition, dam failure would clearly cause a major loss in terms of the economic value of any hydroelectric equipment present on a dam.

Many of Rhode Island's dams were constructed at a time when population densities were much lower than they are today. As a result, many historic dams are now located upstream of neighborhoods and urban centers; these dams, if they were to fail, could cause serious harm and, in some cases, loss of life (Governor's Task Force on Dam Safety and Maintenance 2001). Dam owners are legally responsible for maintaining dam safety, but owners frequently face financial and permitting constraints that hinder their ability to make necessary and timely repairs (Governor's Task Force on Dam Safety and Maintenance 2001).

RIDEM has categorized existing dams in Rhode Island into three safety categories: high hazard, significant hazard, and low hazard (Ch. 3 Figure 7). Hazard level describes the degree of expected collateral damage in the event of a hypothetical dam failure, not the current safety condition of the dam. For example, there may be instances where a dam defined as high hazard presents no imminent threat of failure and instances where a low hazard dam is in danger of immediate failure. In 2011, RIDEM evaluated 668 dams; of these, RIDEM classified 97 as high-hazard dams (i.e., dam failure would result in loss of human life), 82 as significant-hazard dams (i.e., dam failure would not result in loss of human life but would cause significant economic damage), and 488 as low-hazard dams (i.e., dam failure would result in a low level of economic damage and no loss of human life).

Because of the suspected neglect of many historical dams in Rhode Island, dam safety must be evaluated and addressed prior to any construction activities on existing dams. On the positive side, the obligatory evaluation of dam safety prior to hydropower construction can be seen as an opportunity to address dam safety issues that are currently underfinanced.



Ch. 3 Figure 7. Rhode Island Dam Hazard Classification

3.3 Integrated management of watersheds in Rhode Island

SECTION SUMMARY

- The status of each of Rhode Island's watersheds is affected by water quality impairments, obstruction and restoration of fish passage, presence of wastewater and drinking water uses, historical value, recreational use, and legal status, among other things. Installation of hydropower on a river may affect and be affected by these other variables.
- Since the impacts of new hydropower development are greatly contingent upon the varying conditions present in each of Rhode Island's waterways, it is fitting to

employ an integrated, watershed-scale approach to hydropower development that considers each river system's unique ecological, cultural, and regulatory context.

- Integrated watershed management is legally constituted in Rhode Island through the Rhode Island Rivers Council and 13 local watershed councils. The goal of these bodies is the preservation of natural features, cultural features, and recreational opportunities on rivers and watersheds through comprehensive planning of river uses, water quality, and land use.

Effects of hydropower development in Rhode Island may vary considerably from watershed to watershed. For instance, the effects of hydropower development may be influenced by land and water use within a watershed and by the management goals that have been established for each watershed. For this reason, there is a benefit to evaluating the potential impacts of dams within the context of Rhode Island's watershed management plans. A watershed approach to river management entails integrated management of water quality, scenic and cultural value, economic value, and wildlife value, at the scale of the river and its drainage basin.

3.3.1 Watershed Management

Rhode Island's formal commitment to integrated watershed approach began with the establishment of the Rhode Island Rivers Council in 1991, an action intended "to plan for, manage and protect its rivers and watershed resources on an integrated, inter-agency basis that supports systems level planning (RI General Laws 46-28-2)." The goals of the legislation were to preserve natural features of Rhode Island's rivers and their watersheds, preserve cultural and historic features, preserve recreational opportunities, and provide for comprehensive planning of rivers, water quality, and land use. The statute created the Rhode Island Rivers Council to coordinate state policies to protect rivers and watersheds and to strengthen local watershed councils as partners in river and watershed protection.

The Rhode Island Rivers Council submitted the *Rivers Policy and Classification Plan*, which was adopted by the State Planning Council originally in 1998, and amended in 2004. The Classification Plan integrates planning for water quality, land use planning, recreation, and habitat preservation for each river in the state. The plan considers issues such as water quality, land use, and habitat preservation for each water body, and classifies Rhode Island rivers into five freshwater categories: pristine; water supply; open space; recreational; and working rivers.

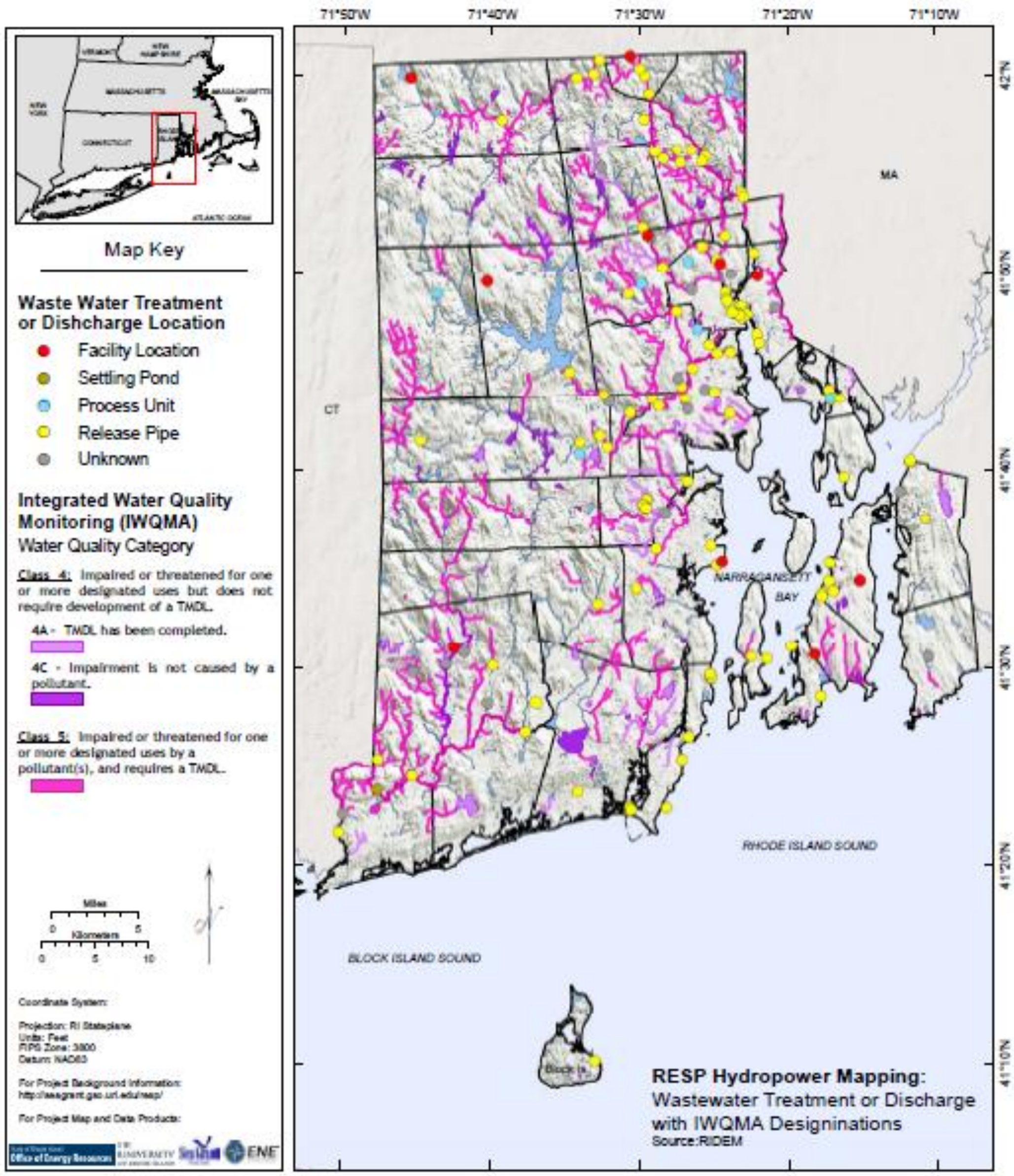
Presence of dams is a key factor in determining the status of a water body under the Rivers Policy and Classification Plan. Pristine waters have no dams or impoundments and are relatively undisturbed and free from pollution. Waters in the water supply category generally contain impoundments for storing public drinking water. Open space waters are located in rural areas and possess high scenic value, relatively undeveloped banks, and good fish and wildlife habitat; they may be characterized by occasional dams or impoundments. Recreational waters are non-urban waters that have some development along their shorelines and may have undergone some level of impoundment or diversion in the past. Working waters are urban waters that are readily accessible, have developed shorelines, and have undergone impoundment or diversion.

The legislation establishing the Rhode Island Rivers Council directed it to establish local watershed councils to implement elements of the Rhode Island Rivers Policy. Local watershed councils, which are made up of representatives of municipalities within each river's watershed,

> "have standing to present testimony in all state and local administrative proceedings which impact on rivers and water quality and shall receive notice, pursuant to rules adopted by the council, from state or city and town agencies regarding proposed actions pertaining to projects, developments and activities located wholly or partially within the watershed represented by the local watershed council" (R.I. General Laws 48-28-8; www.ririvers.org/PDF/FINALnotificationrule.pdf).

The Rhode Island Rivers Council has recognized 13 local watershed councils to play this role. Local watershed councils are designated by the RI Rivers Council to serve five-year terms. Councils receive legal standing and are eligible for state grants through the Rhode Island Rivers Council. Currently, the Rhode Island Rivers Council designates the following nine local watershed councils: Blackstone River Watershed Council / Friends of the Blackstone, Buckeye Brook Coalition, Friends of the Moshassuck; Kickemuit River Council, Narrow River Preservation Association, Pawtuxet River Authority & Watershed Council, Salt Ponds Coalition, Wood-Pawcatuck Watershed Association, and Woonasquatucket River Watershed Council. (www.ririvers.org/watershedcouncils.htm).

To implement integrated watershed management, the Rhode Island Rivers Council and Local Watershed Councils work cooperatively with RIDEM. Both the Clean Water Act and Rhode Island's state water quality legislation designate RIDEM as the principal state authority for water quality. RIDEM also bears regulatory responsibility for fishery restoration in each of Rhode Island's watersheds. The Clean Water Act requires RIDEM to monitor water quality in every water body of the state, identify and address sources of pollution, and develop Total Maximum Daily Load (TMDL) plans (now referred to as Water Quality Restoration Plans) for waters not meeting one or more stated water quality criteria (Ch. 3 Figure 8). RIDEM's TMDL plans prescribe methods to restore degraded water bodies to healthy aquatic ecosystems by identifying water quality goals, pollutant reductions needed to achieve these goals, sources of pollution responsible for degraded water quality, and pollution control actions needed to support the water body's designated uses. Factors identified in RIDEM TMDL plans for each of the state's major watersheds are listed in the next section.



Ch. 3 Figure 8. Integrated Water Quality Monitoring Assessment (IWQMA) Impaired Waters

3.3.2 Major Watersheds in Rhode Island

Not only is each of Rhode Island's watersheds affected by different stressors, but management of each watershed must be framed within a unique set of policy goals informed by these stressors. Plans to establish hydropower facilities on any of Rhode Island's rivers likewise should consider the unique ecological, cultural, and regulatory context of each watershed. The following watershed status summaries are based on information from RIDEM, the Rhode Island Rivers Council, and local watershed councils. More information on watershed characteristics and the potential impacts of hydropower on each watershed is available in RIDEM's Draft

Management Guidance on Siting Considerations for Development of New Hydropower Facilities (RIDEM 2012).

Blackstone River The Blackstone River stretches 46 miles (74 km). Its watershed of 640 square miles (1658 km^2) spans most of northern Rhode Island down to Pawtucket, with the majority of the area located in Massachusetts. A series of steep drops along the length of the Blackstone River provided ideal conditions for the historical development of dams for mill power, and by 1914 nearly every appropriate site along the Blackstone River was occupied by a mill dam. The intensive development of the Blackstone River gave rise to the Industrial Revolution, but at a high environmental cost: pollution of waters, alterations to the river course, and damage to fish populations (Blackstone River Valley National Heritage Corridor Commission 1998). Now classified as a National Heritage River, the Blackstone River is one of RIDEM's highest priorities for anadromous fish restoration, and its four lower dams are scheduled to be modified for fish passage in the near future (RIDEM 2012). Maintenance of streamflow is important due to recreational use of the river. Because of the river's long history of industrial pollution and the presence of wastewater discharges on the river, it is designated by RIDEM as impaired for bacteria, copper, lead, biodiversity impacts, ammonia, nutrients, and dissolved oxygen (RIDEM 2012). The river has been placed on the EPA's 303(d) list of impaired and threatened waters. Contaminated materials are potentially situated in the sediment collected behind the dams at former mill sites on the river. In addition, a Superfund site at the Peterson/Purina landfill is bordered by the Ashton Dam to the North and the Pratt Dam to the south. This landfill contains chlorinated solvents and volatile organic compounds (USEPA 2012), and may make it unwise to pursue hydropower development at the Pratt Dam (CLF 2010).

The Blackstone River has the greatest hydropower potential of any river in Rhode Island. Currently, three FERC-licensed or FERC-exempt hydropower plants operate on the Blackstone, with a combined capacity of 4.8 MW. Four preliminary permits have been filed with FERC to develop new projects on the Blackstone, representing a total of 4 MW of additional capacity. There is interest in increasing the number of hydropower facilities on the Blackstone. In 2010, several towns along the river convened with the Rhode Island Economic Development Corporation, RIDEM, and other Blackstone Valley stakeholders to form the Northern Rhode Island Municipal Energy Collaborative. The purpose of the Collaborative is "to explore opportunities to develop renewable energy in Northern Rhode Island for municipal benefit while at the same time protecting important historic, cultural, and ecological values (Essex Partnership 2012)." In a 2010 feasibility study, the Conservation Law Foundation and Essex Partnership examined the Pratt, Ashton, Albion, Manville, and Elizabeth Webbing dams for possible hydropower development. These groups concluded that four of the five dams "show sufficient promise in terms of energy generation and associated development (CLF 2010)."

Ten Mile River The Ten Mile River drains 52 square miles ($135km^2$), passing though part of Massachusetts, Pawtucket, and East Providence, before emptying into the Seekonk River. The three dams on this river are of interest as sites for potential hydropower development (Essex Partnership 2011). One of these, Hunt's Mill, has been granted a FERC preliminary permit to explore development of a 300 kW hydropower facility (FERC 2012). The Ten Mile River supports a small trout fishery (RI Rivers 2012b), and is one of RIDEM's highest priorities for anadromous fish restoration (RIDEM 2012). The three dams on this river are undergoing or have completed modification for fish passage (RIDEM 2012). During industrialization, the river received waste from numerous textile and metal plating mills, and to this day water quality is considered impaired (RI Rivers 2012b). In addition, the river receives effluents from two Massachusetts wastewater treatment plants (RIDEM 2012). All impoundments along the river show signs of eutrophication, and Turner Reservoir and Omega Pond are classified as impaired for dissolved oxygen (RIDEM 2012). RIDEM is currently developing a TMDL to limit pollutants entering the Rhode Island portion of the river (RIDEM 2012). Two dam ponds (Turner Reservoir and Omega Pond) contain wetlands along the impoundment shorelines (Essex Partnership 2011). Two of the river's dams (Hunt's Mill and Omega Pond) are considered low-hazard; the third (Turner Reservoir) is considered high-hazard (RIDEM 2010a).

Wood-Pawcatuck River The Wood-Pawcatuck River drains most of southwestern Rhode Island and a portion of southeastern Connecticut. About 65% of the watershed remains undeveloped and about 70% of Rhode Island's globally rare species are found within the watershed (RI Rivers 2012c). Although 28 historic dams are found on this river, most were used for milling grain, and did not discharge heavily polluted effluents into the water (RI Rivers 2012c). This watershed is one of RIDEM's highest priorities for anadromous fish restoration because of the prime spawning habitat contained in its upstream reaches. Federal legislation has been submitted that would list the Pawcatuck River under the Wild and Scenic rivers designation (RIDEM 2012; see also Section 3.2.2).

Pawtuxet River The Pawtuxet River watershed encompasses the Scituate Reservoir, 64 ponds, 93 brooks, 7 tributary rivers, and 18 dams (RI Rivers 2012a). The banks of the river are lined with historic dams, mills, and mill villages dating to the industrial era. Most of the dams on the Pawtuxet are privately owned (Essex Partnership). In 2011, the lowest dam on the river was partially removed to enhance fish passage, and other dams may be targeted for fish passage improvements at a later date (RIDEM 2012). The Pawtuxet River receives wastewater treatment discharges from three treatment plants, all of which have undergone extensive upgrades in recent years in order to improve water quality (RIDEM 2012). RIDEM de-listed the Pawtuxet River as impaired for dissolved oxygen in 2008 (RIDEM 2012). Contaminated sediments derived from historical use of the river as a disposal site for industrial effluents continue to present water quality threats (RIDEM 2012), and with highways I-95 and I-295 crossing the watershed, pollution from runoff is now a leading concern (RI Rivers 2012a). Interest exists in developing recreational opportunities along the Pawtuxet River. In 1987, the Pawtuxet River Authority drafted a plan for a series of river walks, canoe access sites, and significant natural areas, but progress towards this goal has been incremental due to lack of funding (RI Rivers 2012a). In 2010, the Essex Partnership was commissioned by the Rhode Island Economic Development Council to evaluate the hydropower potential of fourteen dams on the Pawtuxet River, and concluded that hydropower development would be feasible on all fourteen but economically justified at only nine (Essex Partnership 2010). Dams on the Pawtuxet represent a range of RIDEM hazard classifications, and many are in states of disrepair (Essex Partnership 2010).

Woonasquatucket River The Woonasquatucket River is 19 miles (31 km) long and drains an area of 50 square miles (129 $km^{2)}$ in northern Rhode Island (Woonasquatucket Watershed Council 2012). The watershed is characterized by varied land use, with the upper river flowing through rural areas and the lower river emptying into the urbanized Providence River (RIDEM 2012). It has a rich history, and in 1998 was federally designated as an American Heritage River (RI Rivers 2012d). Fish passage efforts are currently underway on the first four obstructions on the lower Woonasquatucket (RIDEM 2012). Water quality varies according to the degree of urbanization along the river, with the urbanized lower reaches considered impaired for fecal coliform, copper, lead, and zinc (RIDEM 2012). RIDEM's 2007 TMDL for the Woonasquatucket documented stormwater runoff, dry and wet weather, combined sewer overflows, wastewater treatment discharges and other non-point sources of pollution as causes of impaired water quality (RIDEM 2012).

4. REGULATORY CONSIDERATIONS

Existing policies and regulations at both the state and federal levels represent an important source of guidance on hydropower planning and permitting. The Federal Power Act is the most significant piece of federal legislation applicable to hydropower permitting. Other policies, such as the National Environmental Protection Act, Endangered Species Act, Magnuson-Stevens Fisheries Conservation and Management Act, Fish and Wildlife Coordination Act, Rivers and Harbors Act, Clean Water Act, Coastal Zone Management Act, Comprehensive Environmental Response Compensation, and Liability Act, and National Historic Preservation Act, are relevant to specific potential impacts associated with hydropower. While most of these do not specifically address hydropower as a regulated activity, they nonetheless have a bearing on the development of hydropower, since dams and hydropower facilities represent a development activity with potential consequences for the entities or activities that these policies are designed to protect.

Ch. 3 Table 4 summarizes the relevant federal, state, and local agencies and regulations for the permitting of hydropower activities on Rhode Island rivers; it is interesting to note that many of these entities also have jurisdiction over the permitting of river restoration activities.

At the state level, hydropower facilities and the dams that they are located on are subject to multiple laws and regulations designed to protect waterways, wildlife, and public safety. These include the R.I. Water Pollution Control Act, R.I. Freshwater Wetlands Act, RIDEM's program for discharge of dredge material, the R.I. Waters and Navigation Law, RIDEM's Fishways Program, and RIDEM's Dam Safety Program.

In addition, several state and federal policies aim to foster renewable energy projects, including low-head hydropower, through monetary or other incentives. Recognizing that the relative novelty of most forms of renewable energy can at times act as an impediment to economic success, such incentives aim to offset the economic burden associated with installing new and unfamiliar energy technologies.

Ch. 3 Table 4. Permits Needed for FERC Hydropower Projects in Rhode Island (Shaded items also apply to the permitting of river restoration activities).

	AUTHORIZING AGENCY A hydropower project may require authorization by the following agencies to begin development or make modifications.	**APPLICABLE REGULATION** Each agency in the left-hand column must issue a formal approval in accordance with the statute listed below.
FEDERAL	Federal Energy Regulatory Commission (FERC)	License or Exemption application, as prescribed by the Federal Power Act (FPA)
	Army Corps of Engineers (ACOE)	Section 404 of the Clean Water Act (CWA)
	Army Corps of Engineers (ACOE)	Section 10 of the Rivers and Harbors Act
	Fish and Wildlife Service (FWS) and/or National Marine Fisheries Service (NMFS)	Section 7 of the Endangered Species Act (ESA)
	The Advisory Council on Historic Preservation	Section 106 of the National Historic Preservation Act (NHPA): consultation with State Historic Preservation Office (SHPO) and Tribal Historic Preservation Office (THPO)
	Relevant lead federal agency (varies)	National Environmental Protection Act (NEPA)
	National Marine Fisheries Service (NMFS)	Essential fish habitat (EFH) consultation prescribed by Section 305(b) of the Magnuson-Stevens Fisheries Conservation and Management Act (FCMA)
	Fish and Wildlife Service (FWS) and/or National Marine Fisheries Service (NMFS)	Section 30(c) Terms & Conditions (if an exemption); Section 18 Fishway Prescription (if a license)
	Fish and Wildlife Service (FWS)	Fish and Wildlife Coordination Act
STATE	Rhode Island Department of Environmental Management (RIDEM)	R.I. Freshwater Wetlands Act (if near a wetland)
	Rhode Island Department of Environmental Management (RIDEM)	Section 401 of the Clean Water Act (CWA)
	Rhode Island Department of Environmental Management (RIDEM)	Section 30(c) Terms & Conditions (if an exemption)
	Rhode Island Department of Environmental Management (RIDEM) Office of Dam Safety	Notification letter
	Coastal Resources Management Council	Category A or B Assent (if project is located within a coastal area) as outlined in the Rhode Island Coastal Zone Management Program
LOCAL	Municipal building/zoning or planning department	Relevant permits; will vary by municipality

4.1 Federal Regulations

SECTION SUMMARY

- The Federal Power Act (FPA) is the most significant piece of federal legislation applicable to hydropower permitting. The FPA establishes the Federal Energy Regulatory Commission (FERC) as the permitting entity for hydroelectric facilities.
- FERC may give approval to a hydroelectric facility by granting an exemption (for conduit projects and projects under 5MW) or by issuing a license.
- When making permitting decisions, FERC is required to consult with numerous federal and state agencies to make sure that equal consideration is given to power development, fish and wildlife protection, protection of recreational opportunities, and other aspects of environmental quality.
- The Rivers and Harbors Act requires approval by the Army Corps of Engineers (USACE) for construction of structures in or over navigable waters.
- The National Environmental Policy Act (NEPA) requires all major federally funded or permitted projects to submit to an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). Both USACE and FERC must perform NEPA analyses as part of their permitting process for hydroelectric facilities. The two agencies signed an MOU in 2011 stipulating that FERC would be the lead agency for NEPA analyses of hydropower projects.
- The Fish and Wildlife Coordination Act requires projects seeking federal approval to consult with the U.S. Fish and Wildlife Service (USFWS) and with the head of the relevant state agency exercising authority over wildlife resources, to provide for the conservation of fish and wildlife during the permitting of river modification projects.
- The Magnuson-Stevens Fishery Conservation and Management Act requires federal permitting agencies such as FERC to consult with the National Marine Fisheries Service (NMFS) regarding actions that may adversely affect essential fish habitat (EFH) for marine and anadromous species.
- The Endangered Species Act provides for the conservation of threatened and endangered plants and animals and the habitats in which they are found. Section 7 requires federal permitting agencies such as FERC to consult with NMFS and USFWS to ensure that a proposed action is not likely to jeopardize listed species or critical habitat.
- The Clean Water Act contains three provisions that may be relevant to the alteration of existing dams and/or installation of hydropower equipment on these dams: Sections 303(d), 401, and 404. Section 303(d) outlines a list of impaired and threatened waters that fail to meet water quality criteria. This section also requires state water quality agencies such as RIDEM to develop a Total Maximum Daily Load (TMDL) for impaired water bodies. Section 401 requires applicants for federally permitted activities on water bodies to obtain state-issued certificates stating that discharges from the proposed activities will not violate provisions of the Clean Water Act. Section 404 is overseen by the USACE and regulates the discharge of dredged and fill material into waters of the United States.

- The Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund) obligates owners of sites contaminated with hazardous waste to perform or pay for a proper clean-up of these sites. Two Rhode Island dams are on or near Superfund sites.
- The Coastal Zone Management Act requires federally licensed and permitted activities to be consistent with a state's Coastal Zone Management Program. In Rhode Island, FERC must consult with the Coastal Resources Management Council when evaluating hydropower proposals.
- The National Historic Preservation Act (NHPA) established the National Register of Historic Places, a list of districts, sites, buildings, structures, and objects significant in American history. Section 106 requires federal permitting agencies to evaluate the impacts of proposed projects on eligible and listed historic places by consulting with the relevant State Historic Preservation Officer (SHPO).
- Several Federal incentives may be available to support hydropower projects on existing dams in Rhode Island. These include the Federal Hydropower Production Incentive and Federal loans for Small Hydroelectric Power Projects.

4.1.1 Federal Power Act (16 U.S.C. § 12)

The Federal Power Act is the federal legislation that establishes permitting procedures for hydroelectric facilities on navigable rivers. Originally enacted as the Federal Water Power Act in 1920, the Federal Power Act (FPA) has been amended many times since. Prior to enactment of the FPA, individual states had jurisdiction over hydroelectric projects on rivers, despite the fact that the federal government had authority over navigable waters and a duty to maintain their navigability. The FPA resolved this tension by creating the Federal Power Commission (now the Federal Energy Regulatory Commission, or FERC) as a federal licensing entity with authority over hydroelectric projects.

As specified in the FPA, FERC has licensing authority over all hydroelectric projects located in navigable waters, on federal lands, or connected to the interstate electrical grid. When making licensing decisions about a proposed hydropower plan, FERC is required to give equal consideration to: power development; energy conservation; protection, mitigation of damage to, and enhancement of, fish and wildlife (including spawning grounds and habitat); protection of recreational opportunities, and preservation of other aspects of environmental quality (16 U.S.C. 797(f)).

FERC may give approval to a hydroelectric facility by granting an exemption or by issuing a license. Exemptions are available for two types of hydropower projects: conduit hydropower projects and projects that produce less than 5 MW. Conduit projects are those that generate electricity by placing turbines within a pipeline, aqueduct, or other manmade water conduit. Projects qualifying for the conduit exemption must not be located on federal lands and may produce up to 15 MW (18 C.F.R. 4.31(b) (2) (2011)). Projects qualifying for the 5 MW exemption must be sited on non-federal dams built before 1977 or on natural water features (Handbook for Hydroelectric, 2004).

To obtain a FERC hydropower license, prospective hydropower project owners must follow a two-step process. First, they must obtain a preliminary permit, which is valid for three years and reserves a project site for a prospective project owner while all necessary studies are completed. Second, they must apply for an "original," or first-time, FERC license. An original FERC license covers the construction, operating, and maintenance activities of a hydropower project, and is valid for fifty years from the date of issuance. To obtain an original license, an application may follow one of three procedures: the Integrated Licensing Process (ILP), the Traditional Licensing Process (TLP), or the Alternative Licensing Process (ALP). The ILP is FERC's default licensing process; the TLP and the ALP require FERC's approval and are applicable only under certain circumstances.

Through its licensing process, FERC assures that approved projects are "best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of water-power development, for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat), and for other beneficial public uses, including irrigation, flood control, water supply, and recreational and other purposes (16 U.S.C. 803)." FERC licenses include conditions applicable to protection, mitigation, and enhancement of fish and wildlife affected by projects. Such conditions are based on recommendations issued by the National Marine Fisheries Service, the United States Fish and Wildlife Service, and State fish and wildlife agencies pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) . FERC is obligated to grant preference to applications by States or municipalities when issuing licenses (16 U.S.C. 800).

Applicants seeking an original license begin the licensing process by filing a Notice of Intent to File a License (NOI) to declare an interest in generating hydroelectric power at a proposed site and a Pre-Application Document (PAD) that catalogs existing information about a proposed project and its surroundings. A PAD serves as the basis for determining what additional information is needed to support a license application, and must contain information on: adverse impacts associated with the construction, operation or maintenance of a proposed hydropower project; geological and soil characteristics of the site; water resources at the site; fish and aquatic resources in the project vicinity, including any essential fish habitat as defined under the Magnuson-Stevens Fishery Conservation and Management Act; wildlife and botanical resources in the project vicinity; floodplain, wetlands, riparian, and littoral habitats in the project vicinity; rare, threatened and endangered, candidate, or special status species that may be present in the project vicinity, as listed by the Endangered Species Act, and their habitats; existing recreational and land uses and opportunities within the project boundary; visual and aesthetic characteristics of the lands and waters affected by the project; known cultural or historical resources present at the proposed project site and in the surrounding area; socio-economic conditions in the vicinity of the project, such as general land use patterns, population patterns, and sources of employment in the project vicinity; and Indian tribes, tribal lands, and interests that may be affected by the project (18 CFR 5.6).

The PAD must be submitted not only to FERC but to any state agency with responsibility for managing fish, wildlife, and botanical resources, water quality, coastal zone management plan consistency certification, shoreline management, and water resources; the U.S. Fish and Wildlife Service; the National Marine Fisheries Service; Environmental Protection Agency; State Historic Preservation Officer; Tribal Historic Preservation Officer; National Park Service; local, state, and regional recreation agencies and planning commissions; local and state zoning agencies; and any other state or Federal agency or Indian tribe with managerial authority over any part of project lands and waters (18 CFR 5.1(d). By establishing contact with these agencies, the applicant can more readily identify information useful for further characterizing the site and anticipating any impacts of the proposed project. Agencies and the public have 60 days to comment on a proposed project's PAD.

Once an NOI and PAD have been filed, the application goes through a Pre-Filing Process, which lasts until the filing of the actual license application. During the pre-filing stage, FERC conducts a scoping process and a site visit. Scoping includes seeking input from the public, nongovernmental organizations, Indian tribes, and local, state, and federal resource agencies on potential environmental impacts related to the proposed project as well as additional studies that are needed to better understand these issues. Agencies and the public have 60 days to comment on the FERC scoping document.

FERC then works with the applicant and stakeholders to plan a study that will characterize potential effects of the proposed project on environmental, cultural, and recreational resources. A 90-day comment period following submission of the proposed study plan gives the public and relevant agencies an opportunity to recommend additional areas of study to make sure that all potential impacts have been taken into account. The pre-application study, which may take between one and two years to complete, gives the applicant the necessary information to submit a formal license application.

A formal license application must contain a description of the project, along with a statement of environmental information pertinent to the project, called Exhibit E. The application must contain: a description of the river basin where the project is to take place; a list of resources anticipated to experience cumulative effects from a proposed project; a request for a water quality certification (WQC), as required by Section 401 of the Clean Water Act; a description of the process used to address project effects on Federally listed or proposed endangered or threatened species in the project vicinity (in compliance with the Endangered Species Act); a document from the National Marine Fisheries Service (NMFS) and/or the appropriate Regional Fishery Management Council describing any essential fish habitat (EFH) that may be affected by the project (in compliance with the Magnuson-Stevens Fishery Conservation and Management Act); a certification that the project is consistent with the state Coastal Zone Management Program, if the project is located within a coastal zone; anticipated adverse effects on historic properties and a Historic Properties Management Plan (HPMP) to avoid or mitigate any such effects (developed through consultation with the Advisory Council, the State Historic Preservation Officer, Tribal Historic Preservation Officer, National Park Service, members of the public, and affected Indian tribes, where applicable); areas within or in the vicinity of the proposed project boundary that are included in the National Wild and Scenic Rivers System or as wilderness area under the Wilderness Act; all of the information presented in the PAD; and a discussion of environmental effects and unavoidable impacts of the proposed project, and proposed mitigation measures.

FERC then issues a public notice announcing that the application is ready for environmental analysis and requesting comments, protests, and interventions. This "ready for environmental analysis" statement is followed by a 60-day comment period. FERC subsequently judges whether the proposal requires an Environmental Assessment or a more detailed Environmental Impact Statement, as described in NEPA. The public comment period for an Environmental Assessment lasts 30 or 45 days, as specified in the notice accompanying issuance of the environmental assessment. For an Environmental Impact Statement, this period lasts 30 or 60 days.

As part of an environmental assessment or impact statement, FERC evaluates the comments of fish and wildlife agencies made pursuant to Federal Power Act Section 10(j). Section 10(j) requires that projects include conditions for protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat) affected by the development, operation, and management of the project. These conditions are based on recommendations received pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) from the National Marine Fisheries Service, the United States Fish and Wildlife Service, and State fish and wildlife agencies.

When FERC awards a license, it specifies a set of environmental conditions, engineering conditions, and administrative compliance conditions that must be met throughout the life of the project. FERC's Division of Hydropower Administration and Compliance (DHAC) monitors activities at licensed hydropower sites during construction and operation to assure compliance with the conditions laid out in the license. Part 12 of the Federal Power Act pertains to Safety of Water Power Projects and Project Works. Under this section, project owners are required to submit regular Dam Safety Surveillance and Monitoring Reports as outlined in a Dam Safety

Surveillance and Monitoring Plan Outlines (DSSMP) that FERC develops for each licensed project.

4.1.2 Rivers and Harbors Act (33 U.S.C. § 403)

The Rivers and Harbors Act (RHA) of 1899 contains provisions related to dumping in, excavating, and altering the course of navigable waterways of the United States. Navigable waterways are "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past or may be susceptible to use to transport interstate commerce (33 CFR §328)." Section 9 of the RHA makes it unlawful to build a dam in any navigable river, or other navigable water of the United States, without the approval of the Chief of Engineers and Secretary of the Army (33 U.S.C. 401). Section 10 of the RHA prohibits the construction of any structure in or over any navigable water of the United States without the approval of the Chief of Engineers and Secretary of the Army (33 U.S.C. 403). Section 13 of the RHA prohibits the discharge of refuse into navigable waters without the approval of the Chief of Engineers and Secretary of the Army (33 U.S.C. 407); this section remains in effect but has been largely superseded by Sections 402 and 450 of the Clean Water Act.

4.1.3 National Environmental Policy Act (42 U.S.C. § 4321 et seq.)

The National Environmental Policy Act (NEPA) of 1969 requires federal agencies to disclose to the public the environmental costs of any major federally funded or permitted project which could result in environmental degradation, and to develop and consider appropriate alternatives to any proposal characterized by unresolved conflicts concerning alternative uses of available resources (42 U.S.C.S. § 4332). These steps may take place through an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). In comparison to an EA, an EIS involves a more detailed consideration of potential impacts of an action and a more extensive public comment process. NEPA is designed to assure that environmental concerns associated with a proposed project are addressed before the project takes place. However, third parties with an interest in an agency decision who believe that the lead agency has made the wrong decision are allowed to challenge it. When this occurs, the court reviewing a challenge can rule in favor of the agency only if it finds that the agency has considered the full suite of environmental consequences of the proposed action (Stycker's Bay Neighborhood Council v. Karlen, 44 U.S. 223, 227 (1980).

Both USACE and FERC must perform NEPA analyses as part of their permitting process for hydroelectric facilities. To assure that the two agencies are able to carry out their respective regulatory responsibilities with regard to dam permitting without duplicating efforts, an MOU was signed between the USACE and FERC in 2011. The MOU established that (1) FERC would serve as the lead federal agency for the purposes of preparing a NEPA document, and that (2)

USACE and FERC would work closely together, along with the public and other relevant agencies, in preparation of this document (USACE and FERC 2011).

4.1.4 Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.)

The Fish and Wildlife Coordination Act of 1934 was enacted to "provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation (16 USC 661)." The Fish and Wildlife Coordination Act requires that the federal agencies or entities seeking approval from federal agencies to impound or otherwise modify a body of navigable water first consult with the U.S. Fish and Wildlife Service and with the head of the relevant state agency with authority over wildlife resources. The purpose of this consultation is to provide for "the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development (16 USC 662)."

The Fish and Wildlife Coordination Act obliges the USFWS and relevant state agencies to be as thorough as possible in making recommendations for the conservation of fish and wildlife in conjunction with river modification projects, and obliges the federal agency with permitting authority on a given project to take these recommendations into account. Section 10(j) of the Federal Power Act reiterates this directive and refers directly to the Fish and Wildlife Coordination Act. In the case of hydropower projects on dams in Rhode Island, RIDEM is the relevant state wildlife conservation agency and FERC is the federal permitting authority.

4.1.5 Endangered Species Act (16 U.S.C. 1531 et seq.)

The Endangered Species Act of 1973 provides for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The section most relevant to hydropower projects is Section 7 (16 U.S.C. § 1536(a)(2)). This section outlines procedures for interagency cooperation to conserve federally listed species and designated critical habitats. Critical habitats are defined as specific areas occupied by a listed species as endangered or threatened under the ESA. Critical habitat areas possess physical or biological features that are essential to the conservation of the species and which may require special management considerations or protection.

Section 7(a)(2) requires federal agencies undertaking, funding, permitting, or authorizing an action to first consult with the NMFS (for marine and anadromous species), or the USFWS (for fresh-water species and land-based wildlife) to ensure that the action is not likely to jeopardize the continued existence of listed species or adversely modify designated critical habitat. In the case of hydropower, FERC is the permitting agency that is required to consult with

FWS and NMFS; the consultation requirement embodied in Section 7 of the ESA is also reflected in FERC license application guidelines (18 CFR §5).

4.1.6 Magnuson Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801 et seq.)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) of 1976 governs fishing activities in federal waters through the establishment of eight regional fisheries management councils, which are charged with rebuilding depleted stocks and managing healthy ones. In recognition of the importance of habitat to fish populations, the MSFCMA prescribes documentation of essential fish habitat (EFH) for each species it manages.

Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act and its implementing regulations at 50 CFR 600.920 require federal agencies to consult with the National Marine Fisheries Service (NMFS) regarding actions that they undertake, fund, or approve that may adversely affect essential fish habitat (EFH) for marine and anadromous species. In the case of a federally permitted hydroelectric dam, FERC must submit an EFH Assessment to NMFS, describing potential adverse effects of the action on EFH and the species dependent on it, as well as proposed mitigation measures. The EFH Assessment may also be incorporated into documents prepared for other purposes, such as Endangered Species Act (ESA) Biological Assessments pursuant to 50 CFR part 402 or National Environmental Policy Act (NEPA) documents and public notices pursuant to 40 CFR part 1500. The Federal Power Act incorporates the MSFCMA EFH consulting requirement into the hydropower license application process by directing applicants to include an assessment of EFH effects of the proposed project in Exhibit E of their application packet.

4.1.7 Clean Water Act

The purpose of the Clean Water Act (CWA) of 1972 is to restore and maintain the quality of the waters of the United States. The Clean Water Act contains three provisions that may be relevant to the alteration of existing dams and/or installation of hydropower equipment on existing dams: Section 303(d), Section 401, and Section 404.

The EPA’s 303(d) list is a list of impaired and threatened waters that fail to meet water quality criteria for one or more pollutants based on required technology-based pollution controls alone. States are required to monitor water quality at all rivers and evaluate progress towards restoration goals. When a water body is placed on the 303(d) list, state water quality agencies are required to develop a Total Maximum Daily Load (TMDL) for the water body. A TMDL is a water quality restoration plan that identifies the maximum amount of a pollutant that a listed water body can safely receive, as well as the sources of pollution that are currently causing the pollutant(s) to exceed maximum acceptable values and the actions necessary to reduce pollutants to these levels. In Rhode Island, the RIDEM Office of Water Resources has completed TMDLs addressing 141 causes of water pollution on 86 waterbodies (RIDEM 2011). The water quality activities of RIDEM are discussed in further detail in Section 0 of this report.

Section 401 of the CWA requires applicants seeking federal licenses for activities on water bodies to obtain certificates stating that discharges from the proposed activities will not violate provisions of the Clean Water Act. Section 401 Certifications are issued by states; in Rhode Island, RIDEM is the agency responsible for approving Section 401 Certifications. States have successfully used Section 401 to make hydropower dam owners comply with water flow, antidegradation, water quality, and fish passage requirements that the state deems necessary to achieve water quality and habitat goals (Baer 2007).

Section 404 of the CWA, overseen by the USACE, regulates the discharge of dredged and fill material into waters of the United States, including wetlands. A hydroelectric developer will likely need to obtain a CWA permit to modify an existing dam if the project involves adding dredged or fill material to the river to make modifications necessary to produce hydroelectricity. Authority for implementing Section 404 is shared by the EPA and the USACE. USACE issues individual permit decisions and jurisdictional determinations; develops policy and guidance; and enforces Section 404 provisions, while EPA develops and interprets environmental criteria used in evaluating permit applications, enforces Section 404 provisions, and has authority to veto USACE permit decisions.

4.1.8 Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund (42 U.S.C. §§ 9601 et seq.)

The Superfund Act of 1980 was enacted to create a mechanism obliging owners of sites contaminated with hazardous waste to perform or pay for a proper clean-up of these sites. CERCLA may come into play during the renovation of existing dams for hydropower if these dams are located in or near a Superfund site. CERCLA operates through a fund designated for use by the Environmental Protection Agency (EPA) to use for clean up of hazardous wastes sites. After EPA has cleaned up a site, CERCLA enables the EPA to sue the parties responsible for the hazardous waste on the site for recuperation of the costs of cleaning it up. The Centredale Superfund Site, located on the Woonasquatucket River at Allendale Mill Pond and Lyman Mill Pond, contains dioxin, PCBs, volatile organic compounds, and metals in sediments, wetlands and surface waters. A clean-up of this site is currently underway. The Peterson/Puritan Superfund Site, located on the Blackstone River, includes the Pratt Dam, which is currently non-operational and is not impounding water; any effort to restore such a dam for hydropower would have to consider the effects of refilling the impoundment, and the legal responsibility for clean-up of such a site (CLF 2010).

4.1.9 Coastal Zone Management Act (16 U.S.C. § 1451 et seq.)

The Coastal Zone Management Act (CZMA) of 1972 enables states to develop federally approved Coastal Zone Management Plans to "preserve, protect, develop, and where possible, restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations". Section 307(c)(3) of the CZMA requires that all federally licensed and permitted activities be consistent with a state's Coastal Zone Management Program. FERC licenses are among the many federal actions that must be consistent with a state's Coastal Zone Management Program. The FPA requires FERC to consult with the relevant state CZMA agency when evaluating a hydropower proposal. In Rhode Island, this agency is the Coastal Resources Management Council. The CRMC's jurisdiction extends 200 feet inland of any coastal feature, and includes all power-generating activities in the state with a capacity of greater than 40MW (Coastal Resources Management Program Sec. 320(A)). Thus, all hydropower proposals in Rhode Island must be found consistent with the state's Coastal Zone Management Program. More information on required approvals by the CRMC can be found in Section 4.2.7 of this report.

4.1.10 National Historic Preservation Act (16 U.S.C. § 470)

The National Historic Preservation Act (NHPA) was enacted in 1966 to assure that "the historical and cultural foundations of the Nation should be preserved as a living part of our community life and development in order to give a sense of orientation to the American people (16 U.S.C. 479b(2))." The NHPA's central accomplishment was the establishment of a National Register of Historic Places that lists "districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, engineering, and culture (16 U.S.C. 470a(a))."

In addition, NHPA provides for the establishment of a State Historic Preservation Officer (SHPO) in each state. The role of a SHPO is to implement a State Historic Preservation Program, nominate eligible properties to the National Register, administer federal assistance for historic preservation within the state, and to cooperate with federal agencies, local governments, organizations, and individuals to ensure that historic properties are taken into consideration at all levels of planning and development. At the time of this writing, Rhode Island's SHPO is Edward Sanderson at the Rhode Island Historic Preservation & Heritage Commission (NCSHPO 2012). The RI Historic Preservation Act (R.I. Gen. Laws 42-45 et seq.) is the state authority under which the Rhode Island Historical Preservation and Heritage Commission administers its programs including the review of state undertakings. The 1992 Amendments to the NHPA enabled tribal representatives to take on the role of a SHPO for their respective tribes by designating a Tribal Historic Preservation Officer (THPO; Section 101(d)(2)). At the time of this writing, the THPO Narragansett Indian Tribal Historic Preservation Officer (NITHPO) is John Brown (NATHPO 2012).

Section 106 of the NHPA requires federal agencies such as FERC to evaluate the impacts to eligible and listed historic places of the projects ("undertakings") that they conduct, fund, or approve. Section 106 also requires federal agencies to consult with the Advisory Council on Historic Preservation, a 23-member council made up of members of the public and private sectors, also established by the NHPA. The Advisory Council's implementing regulations, "Protection of Historic Properties" (36 CFR Part 800), lay out the complete Section 106 process.

To begin the Section 106 process, the lead federal agency responsible for the undertaking must first identify all parties to a consultation – relevant SHPO and THPO, local governments, the public, and additional parties with a special interest in the undertaking in question. Next, the lead agency identifies the Area of Potential Effect (APE) affected by the proposed undertaking, and gathers information from consulting parties, other experts, and written sources to identify historic properties in the APE. If the lead agency finds that there are historic sites in the APE, it assesses the anticipated effects of the proposed undertaking on these properties to determine whether any of these effects are adverse. An adverse effect is one that "may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association (36 CFR Part 800.5)." If the lead agency issues a finding of no adverse effect, it must give consulting parties 30 days to review the finding and contest it if they choose. If the lead agency finds that an undertaking may cause adverse effects to historical properties, it engages consulting parties to develop alternatives or modifications to the proposed undertaking that could avoid, minimize, or mitigate these effects. Following the consultation, the lead agency commits to a memorandum of agreement with SHPO/THPO.

FERC and the Advisory Council on Historic Preservation developed a set of "Guidelines for the Development of Historic Properties Management Plans for FERC Hydroelectric Projects (FERC and Advisory Council on Historic Preservation 2002)." These guidelines encourage hydropower license applicants to submit a Historic Properties Management Plan (HPMP) prior to, or along with, their FERC license application. An HPMP considers and plans to manage the effects on historic properties of activities associated with construction, operation, and maintenance of hydropower projects. A complete HPMP should identify the nature and significance of historic properties that may be affected by a project, any proposed improvements to project, goals for the preservation of historic properties, and plans for public access (http://www.ferc.gov/industries/hydropower/gen-info/guidelines/hpmp.pdf). According to the Council's regulations, license applicants should consult with the relevant SHPO, THPO, and Indian tribes when developing their HPMPs, and should include in their HPMPs procedures for consulting with these entities throughout the life cycle of the project.

4.1.11 Federal Hydropower Incentives

Over the years, a variety of federal incentives have been instituted to foster development of renewable energy. These are sometimes of short duration and are always subject to change, due to Congressional reauthorization processes. Several federal incentives exist specifically to foster small hydropower projects and hydropower projects on existing dams. Others are more general, applying to a wider variety of renewable energy projects, but can be used by hydropower developers. These include the Department of Energy Loan Guarantee Program, the Renewable Energy Production Tax Credit, the Public Utilities Regulatory Policy Act, and Clean Renewable Energy Bonds. The following incentives apply exclusively to hydropower. Several general incentives that can be used for hydropower are presented in Chapter 1, Section 5 of this document.

The federal *Hydropower Production Incentive* program, enacted in 2005 (42 U.S.C.S. § 15881), is available to non-federal entities generating power on previously existing dams or conduits." To be eligible, a project must be installed between 2005 and 2015 on a dam or conduit constructed before August 8, 2005 and may not involve any construction or enlargement of impoundment or diversion structures. Qualifying facilities may receive incentive payments for a period of ten fiscal years, starting in the year in which the facility becomes eligible. The value of the incentive payment offered is based on the amount of power generated. Qualifying facilities are eligible to receive 1.8 cents per kW hour, adjusted for inflation, up to a maximum of $750,000 per calendar year.

Federal loans for *Small Hydroelectric Power Projects*, established in 1978 (16 U.S.C. § 2701), aim to "encourage municipalities, electric cooperatives, industrial development agencies, nonprofit organizations, and other persons to undertake the development of small hydroelectric power projects in connection with existing dams which are not being used to generate electric power." According to the law, any of these entities is eligible to seek a loan from the Department of Energy covering up to 90 percent of the costs associated with feasibility studies and license application preparation. In addition, hydropower developers may seek loans from the Department of Energy covering up to 75 percent of the cost of constructing a hydroelectric project. For the purposes of this statute, "small hydroelectric power project" is defined as any hydroelectric power project that is located at the site of any existing dam, uses the water power potential of such a dam, and has no more than 30,000 kW of installed capacity. Hydropower projects that operate without the presence of a dam are also eligible. When awarding these loans, the Department of Energy gives preference to projects that do not have other financing available, and that are expected to provide valuable proof-of-concept information on small scale hydropower.

The *Hydroelectric Efficiency Improvement Incentive*, enacted in 2005 (42 U.S.C. 15882), aims to make existing hydropower facilities more efficient. Incentive benefits must be used to make capital improvements that are directly related to improving the efficiency of existing facilities by at least 3 percent. The benefits that any one project may receive are capped at 10 percent of the total cost of the capital improvements, and may not exceed $750,000 at a single facility. Appropriations to this program end in 2015.

4.2 Rhode Island Regulations

SECTION SUMMARY

- Rhode Island Water Quality Regulations require new uses of stream water and groundwater to obtain a permit from RIDEM if they include withdrawals of more than 10,000 gallons of water per day.
- The R.I. Freshwater Wetlands Act may apply to hydropower projects located near wetlands, particularly where a wetland is present as a result of the impoundment created by the dam that will support hydropower. This Act requires project owners to solicit a wetlands permit from RIDEM.
- Rhode Island Fish and Wildlife legislation authorizes RIDEM to construct fishways around and through existing dams in the state. Dam owners are required to cooperate with RIDEM in this endeavor.
- Rhode Island legislation on Inspection of Dams and Reservoirs authorizes RIDEM to inspect every dam in Rhode Island for safety. If RIDEM finds a dam to be unsafe (i.e., if there is reasonable cause to believe it poses a danger to life or property), then RIDEM has the authority to require alterations to the dam to minimize risk.
- New hydropower facilities fall under the jurisdiction of the Rhode Island Coastal Resources Management Council (CRMC) if they are within 200 ft (61 meters) of any coastal feature or if they produce over 40 MW of electricity anywhere within the state. Facilities in these categories must comply with the Coastal Resource Management Program (also known as the “Redbook”) and any applicable Special Area Management Plans (SAMPs).
- In recent years, the state of Rhode Island has established a variety of incentives to spur the development of renewable energy in the state. The most significant is the Renewable Energy Standard, which guarantees a market for renewable energy by requiring electrical distribution companies to purchase a certain percentage of energy from renewable sources each year.

4.2.1 RIDEM Water Diversion Permit

RIDEM authority over projects involving water diversions stems from the Water Pollution Control Act (R.I. Gen. Laws 46-12) and its associated Water Quality Regulations, and from the Freshwater Wetlands Act (R.I. Gen. Laws 2-1-18 et seq.). The Water Pollution Control Act is the enabling legislation for State authority over water resources with regards to pollution, and designates RIDEM as the permit-granting authority overseeing discharge of pollutants as regulated by the Clean Water Act (33 U.S.C. § 1251 et seq.) in Rhode Island. The Rhode Island Water Quality Regulations of 2006 “provide for the protection of the surface waters from pollutants so that the waters shall, where attainable, be fishable and swimmable, be available for all designated uses, taking into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and also taking into consideration their use and value for navigation, and thus assure protection of the public health, safety, welfare, a healthy economy and the environment."

RIDEM evaluates applications for water diversion permits by using a Streamflow Depletion Methodology (SDM). The SDM is a tool that calculates "the volume of water that can be extracted from a stream (whether as direct stream withdrawals or indirect groundwater withdrawals) while still leaving sufficient flow to maintain habitat conditions essential to a healthy aquatic ecosystem (RIDEM 2010b)." Under this methodology, RIDEM calculates allowable water depletions from streams and groundwater according to the natural and human needs and influences within each watershed. New uses of stream water and groundwater are required to consult with RIDEM about obtaining a permit if they represent withdrawals of more than 10,000 gallons of water per day. RIDEM issues a permit only if the project is determined to leave "enough remaining capacity in the net available streamflow depletion to accommodate the proposed withdrawal." Permit requirements for hydropower projects will vary on a case by case basis and depend on both the size of the streamflow diversion resulting from a project and the streamflow requirements of the watershed.

4.2.2 Wetlands Permit

The R.I. Freshwater Wetlands Act (R.I. Gen. Laws 2-1-18 et seq.) and its associated Freshwater Wetlands Rules and Regulations were instituted to "to preserve the purity and integrity of the swamps, marshes, and other fresh water wetlands of this state (R.I. Gen. Laws 2-1-19)." The Freshwater Wetlands Act requires landowners to obtain a permit from RIDEM in order to "excavate; drain; fill; place trash, garbage, sewage, highway runoff, drainage ditch effluents, earth, rock, borrow, gravel, sand, clay, peat, or other materials or effluents upon; divert water flows into or out of; dike; dam; divert; change; add to or take from or otherwise alter the character of any fresh water wetland (R.I. Gen. Laws 2-1-21)." Hydropower projects located near wetlands may require freshwater wetlands permits, particularly where a wetland is present as a result of the impoundment created by the dam that will support hydropower.

4.2.3 Discharge of Dredge Material

RIDEM is authorized by the federal CWA and state Water Pollution Control Act to regulate discharge of pollutants, including dredge spoils, in waterways within the state of Rhode Island. The statute defines a pollutant as "any material or effluent which may alter the chemical, physical, biological, or radiological characteristics and/or integrity of water, including but not limited to dredged spoil (R.I. Gen. Laws 46-12-1)." To this end, RIDEM issues permits for disposal of dredge spoil and establishes water quality standards that conform to the EPA's applicable water quality rules and regulations with regards to the dredging and disposal of sediments. Hydropower projects that involve the dredging and/or filling of a body of water in order to install power generation equipment may require a water quality permit from RIDEM.

4.2.4 Obstructions to Navigation

Rhode Island's Waters and Navigation law authorizes RIDEM to remove any unlawful or unauthorized structure deposited within the tidewaters of Rhode Island when that structure is liable to cause or become a danger to the safe and convenient use of the waters for navigation and other lawful purposes (R.I. Gen. Laws 46-6-8).

Instances involving the filling of public tidelands are subject to Rhode Island General Laws Section 46-6-1, "Deposit of dirt and other substances in public tidewaters." Under this section, RIDEM regulates the depositing of mud, dirt or any other substances in the public tidewaters of Rhode Island. This statute would apply to construction of a hydropower project if the project requires a developer to deposit any substances within the tide waters of Rhode Island. Noncompliance may result in a fine of $100 for each offense. The law specifically prohibits the deposit of substances into the Blackstone or Seekonk Rivers if it is done in such a way which would inhibit the navigability of those rivers (R.I. Gen. Laws 46-6-4).

4.2.5 Fishways

Rhode Island Fish and Wildlife legislation authorizes RIDEM to construct fishways around and through existing dams in rivers in the state, "[f]or the purpose of providing for the passage of anadromous fish species to their traditional spawning grounds in fresh water (R.I. Gen. Laws 20-12-4)." Dam owners are required to cooperate with RIDEM plans for fish passage and are not held liable for any damage that occurs to the dam as the result of the fishway construction.

4.2.6 Dam Safety Program

Rhode Island legislation on Inspection of Dams and Reservoirs authorizes RIDEM to inspect every dam in Rhode Island for safety (R.I. Gen. Laws 46-19-1). This statute enables RIDEM agents to enter a person's private property for the purpose of inspecting a dam without rendering themselves liable for trespass. Dam owners and operators are required to facilitate safety evaluations by submitting a description of their dam or reservoir to RIDEM. If RIDEM finds a dam to be unsafe (i.e., if there is reasonable cause to believe it poses a danger to life or property), then RIDEM has the authority to require alterations to the dam to minimize risk. In addition, RIDEM must visually inspect high-hazard dams every two years, and significant-hazard dams every five years (Section 3.2.3 contains further information on the RIDEM dam hazard classification scheme).

Rhode Island legislation on Emergency Action Plans (R.I. Gen. Laws 46-19-9) requires cities and towns with high- or significant-hazard dams within their municipal limits to file an Emergency Action Plan (EAP) for each dam. EAPs are to be updated on an annual basis and filed with the Rhode Island Emergency Management Agency (EMA), RIDEM, the chief of the local police department, and the local municipality's emergency management official. Dam owners must reimburse the city of town for the costs of assembling the EAP within 90 days of EAP completion. RIDEM may also elect to request EAPs from owners of low-hazard dams.

Further dam safety requirements are given in the RIDEM Rules and Regulations for Dam Safety. Under these regulations, owners of high- and significant-hazard dams must obtain a permit from RIDEM's Dam Safety Program whenever they perform repairs to their dams. Repairs requiring a permit include removal of trees, excavation on the embankments, reinforcement of embankments, and removal of any major structural component of a dam (RIDEM 2007).

4.2.7 CRMC Permit

New hydropower facilities may require a CRMC Category Assent if they are within 200 ft (61 meters) of any coastal feature or if they produce over 40 MW of electricity anywhere within the state. The CRMC's Coastal Resource Management Program (also known as the "Redbook") explains that since it would be impractical for the CRMC to evaluate every single proposed activity that comes under its jurisdiction, the CRMC's policy is to require permits from those proposed projects that would, in the CRMC's judgment, result in potential conflict with the Redbook or with any Special Area Management Plans (SAMPs) pertinent to the area where the activity will take place, or that would result in environmental harm to the coastal zone. A Special Area Management Plan is an ecosystem-based management strategy for preserving and restoring a geographically bounded ecological system, developed by the CRMC in consultation with municipalities, state agencies, and community organizations.

If CRMC notifies a proposed developer that a Category B Assent is required, the developer must demonstrate that the proposed project: is necessary; complies with all local zoning ordinances, building codes, flood hazard standards, and all safety codes, fire codes, and environmental requirements; will not result in significant impacts on the abundance and diversity of plant and animal life; will not result in major changes to water circulation or quality; will not result in significant impacts to areas of historic and archaeological significance; will not result in significant conflicts with water-dependent uses and activities such as recreational boating, fishing, swimming, navigation, and commerce; and that measures have been taken to minimize any adverse scenic impact. The CRMC also exercises federal consistency review for any hydropower project in the coastal zone that requires a FERC license pursuant to 15 CFR § 930 Subpart D (see Sections 4.1.1 and 4.1.9 herein).

4.2.8 Rhode Island Hydropower Incentives

In recent years, the state of Rhode Island has established a variety of incentives to spur the development of renewable energy in the state. The most significant is the Renewable Energy Standard, which guarantees a market for renewable energy by requiring electrical distribution companies to purchase a certain percentage of energy from renewable sources each year. Other incentives foster distributed generation, net metering, interconnection, and tax incentives. These incentives apply to multiple forms of renewable energy, including hydropower, and are discussed in detail in Chapter 1, Section 5 of this report.

In addition, Rhode Island offers a tax credit to hydroelectric power developers to help offset the costs of hydropower equipment installation (R.I. Gen. Laws § 44-30-20). Small hydroelectric power production facilities (defined as facilities with 15,000 kW of installed capacity) constructed on existing dams (defined as dams built before May 20, 1981 not requiring construction or enlargement of the impoundment in order to generate hydroelectric energy) are eligible for the credit. The tax credit is calculated according to the installation costs associated with the project. The credit may equal no more than 10 percent of the installation costs associated with the facility, or $500,000 in expenditures, for a maximum income tax credit of $50,000 dollars.

4.3 Rhode Island Municipal Ordinances

SECTION SUMMARY

- Municipalities may establish dam management districts (DMDs) to manage the services provided by dams and the possible risks posed by dams that no longer serve a purpose. Two DMDs have been established in Rhode Island: the Boone Lake DMD in Exeter and the Pascoag Reservoir/Echo Lake DMD in Burrillville and Glocester. Hydropower projects proposed within a DMD should consult with these entities.
- Rhode Island's Soil Erosion and Sediment Control law includes a model ordinance that may be adopted by municipalities to control erosion. South Kingstown, Providence, Cranston and Cumberland have passed soil erosion and sediment control ordinances. Hydropower construction activities in these locations must comply with the requirements of these ordinances if they are expected to result in erosion.

4.3.1 Local Dam Management Districts

Rhode Island law allows for the creation of dam management districts (DMDs) through municipal ordinances "to protect the values that dams provide, or mitigate the risk posed by dams that no longer serve any useful purpose (R.I. Gen. Laws § 45-62-1)." Municipalities may create more than one DMD per city or town; conversely, several municipalities may create one or more DMDs jointly. DMDs are legally constituted as corporations and are administratively separate from municipalities and the state. They may encompass all or part of the municipalities that establish them. An ordinance establishing a DMD must set forth the boundaries of the DMD, provide for governance and administration of the DMD, and establish requirements for annual reporting by the DMD to the municipality.

It is within the purview of a DMD to improve dam safety though dam repairs, maintenance, management and/or removal; to undertake public education programs to inform residents of the district about procedures for proper maintenance and operation of dams; to caution residents about the implications for failing to meet accepted dam safety practices; and to raise funds for the expenses associated with the operation of the DMD.

Two DMDs have been created in Rhode Island since the enactment of the statute. The Boone Lake DMD was created by Exeter in 2007 to collect money for the costs of maintaining and repairing State Dam No. 219 (Town of Exeter 2007). The Pascoag Reservoir/Echo Lake DMD was created by Burrillville and Glocester in 2009 to apportion the costs of maintenance and repair among the owners of property within the DMD, which includes Pascoag Reservoir/Echo Lake and the properties which have direct access to the lake (Pascoag Reservoir/Echo Lake Dam Management District 2010).

4.3.2 Soil Erosion Ordinances

Rhode Island's Soil Erosion and Sediment Control law (§ 45-46-5) includes a model ordinance that may be adopted by municipalities where "excessive quantities of soil are eroding from certain areas that are undergoing development for non-agricultural uses such as housing developments, industrial areas, recreational facilities, and roads." When adopted as written, the model ordinance requires a building permit for any activity that disturbs existing vegetation, grades, and contours of land in a way that increases the potential for soil erosion. To obtain the permit, a project developer must file an erosion and sediment control plan, which includes proposed measures to control erosion and sediments while the activity is conducted. When approving a plan, a building official may attach conditions which are reasonably necessary to prevent soil erosion, such as erecting walls, drains, and dams. South Kingstown, Providence, Cranston and Cumberland have passed soil erosion and sediment control ordinances based on the state model ordinance (South Kingston, R.I., Code § 20-58; Providence, R.I., Code § 5-104; Cranston, R.I., Code § 15.28.040; Cumberland, R.I., Code § 20-107). Hydropower construction activities taking place within these towns require a building permit if they are expected to result in erosion of sediments.

4.4 Non-Governmental Organization Certification: Low Impact Hydropower Institute

SECTION SUMMARY

- The Low Impact Hydropower Institute (LIHI) Hydropower Certification Program is a voluntary nationwide certification program designed to reward and promote environmentally responsible hydropower facilities.
- LIHI certification criteria include streamflow, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resource protection, and recreational resources protection.

The Low Impact Hydropower Institute (LIHI) Hydropower Certification Program is a voluntary nationwide certification program designed to reward and promote environmentally responsible hydropower facilities. LIHI accomplishes this goal by granting a certification to facilities that meet its criteria for low-impact hydropower. As a credible, widely-accepted standard of hydropower design and operation, the LIHI certification is meant encourage conscientious energy consumers to purchase energy from these facilities in preference over others. LIHI awards its certification only to those hydropower facilities that have "environmental impacts that are low compared to other hydropower facilities based on objective environmental criteria (LIHI 2011)." Criteria include streamflow, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resource protection, and recreation resources protection.

Facilities that are eligible to apply for LIHI certification include existing hydropower facilities (defined as those facilities operating prior to 1998) and "new" hydropower facilities (defined as existing dams that have added or increased power generation capacity after August of 1998). New hydropower facilities are eligible only if their construction did not involve creation of a new dam or impoundment, lead to any adverse changes in water flow, or take place in spite of a prior recommendation by relevant resource agencies that the dam be removed (exceptions are considered if the added or increased capacity resulted in specific measures to improve fish, wildlife, or water quality protection at the existing dam).

In many states, LIHI certification is a requirement to participate in Renewable Energy Certificate (REC) markets and there is therefore an economic incentive for facilities to become certified (CLF 2010). The only LIHI-certified project currently in Rhode Island is the Pawtucket No. 2 Small Hydroelectric Project on the Blackstone River, a 1.3-MW facility owned by Pawtucket Hydropower, LLC. The facility has been LIHI-certified since 2004 (LIHI 2012).

5. RESP HYDROPOWER STAKEHOLDER WORKSHOPS

SECTION SUMMARY

- The RESP hydropower stakeholder process included two all-day workshops that brought together a diverse set of state and federal agencies, non-governmental organizations, and other experts to discuss a wide range of implications relating to hydropower development in Rhode Island.
- The goal of the first workshop was to review and provide recommendations on RIDEM's Draft Guidance on Siting Considerations for Development of New Hydropower Facilities and to discuss how RESP research could be tailored to complement the RIDEM document.
- The goal of the second workshop was to work with stakeholders and key decision makers to explore the potential for river restoration and low-impact hydropower development to thrive synergistically on Rhode Island rivers.
- One of the main contributions proffered by stakeholder participants is the evolving vision of low-impact hydropower development as an avenue to attract attention and funding to support fish restoration, dam safety upgrades, and other needed improvements to Rhode Island rivers. Stakeholders described an ideal scenario wherein river restoration and hydropower development are managed synchronously, rather than through a piecemeal approach.

The RESP relied on several forms of stakeholder participation to ground hydropower research in a Rhode Island context, identify new needs and questions for further investigation, and enable key stakeholder groups to provide input into statewide siting guidance on hydropower development. A subsequent chapter of this report, Stakeholder Process and Public Engagement, discusses the evening stakeholder meetings that were held throughout the RESP process to share information and opinions on wind, solar, and hydroelectric energy options for Rhode Island. This section describes an additional stakeholder component that was specific to the hydropower portion of the RESP: a series of two all-day workshops that brought together a diverse set of state and federal agencies, non-governmental organizations, and other experts to discuss a wide range of implications relating to hydropower development in Rhode Island.

5.1 Rhode Island Hydropower Workshop I

On February 28, 2012, the URI Outreach Center and RIDEM convened an all-day Hydropower Workshop at URI's Bay Campus. The goal of the workshop was to build agreement on ways that the State should guide environmentally sustainable hydropower development in Rhode Island. Thirty-four people attended the workshop, representing a range of state and federal agencies, non-governmental organizations, and other groups. Participants are listed in Ch. 3 Table 5.

The main focus of the day's activities was to review and provide recommendations on RIDEM's Draft Guidance on Siting Considerations for Development of New Hydropower

Facilities (RIDEM 2012), and to discuss how RESP research could be tailored to complement the RIDEM document. To facilitate conversation, the URI and RIDEM team identified the following objectives for the workshop:

- Outline the state's current approach/strategy for exploring and managing hydro-electric power.
- Confirm that the data being produced by the RESP is appropriately informing the siting guidance process.
- Provide feedback to RIDEM on draft guidance that represents a spectrum of stakeholders and interests.
- Identify additional informational needs and known sources of further information.
- Plan next steps for RIDEM guidance document and broader polices for environmentally sustainable hydroelectric power in Rhode Island.

The workshop began with overviews of the draft RIDEM document and the RESP project, presentation of the RESP hydopower online map viewer (described in the RI Energy.org Chapter of this Report), and summaries of fish restoration and water quality considerations related to dams on Rhode Island rivers. However, the bulk of the workshop consisted of small-group discussions on five topics: (1) the division of roles between the RIDEM draft guidance document and the RESP; (2) additional issues and information that should be considered in the RIDEM document; (3) issues that should not be included in the RIDEM document; (4) any additional data needed; and (5) opportunities, constraints and next steps to developing economically viable and environmentally sustainable hydropower in RI.

Comments contributed by stakeholders during small-group discussion were vital to improving both the RIDEM guidance document and the RESP project. With regard to the appropriate division of roles between the RIDEM guidance document and the RESP report, groups largely agreed that the RIDEM document should be more narrowly focused on the environmental impacts of hydropower and the regulatory framework surrounding them, while the RESP report should have a broader focus, encompassing hydropower potential at selected dams across the state, and discussing hydropower in the wider context of fishway restoration, watersheds, and other uses of Rhode Island's rivers.

With regard to informational needs, stakeholders contributed the following suggestions, which were incorporated into the RIDEM guidance document and/or the RESP report:

- Changing conditions: Stakeholders stressed that RIDEM and RESP analyses are based on current technologies and conditions, and are subject to change as technologies improve and river conditions change.
- Mechanical versus electrical power: Stakeholders mentioned that few of Rhode Island's dams were built to generate electricity; most were originally built to power mill machinery using mechanical, not electrical, forces. Some stakeholders questioned how well these dams could be adapted for generation of hydroelectric power, and suggested the potential for additional and unexpected challenges due to this distinction.

- Fish passage: Stakeholders pondered what should happen to existing fish passage modifications on dams converted to hydropower: Will dam developers be required to refund costs of existing mitigation measures? Will they be required to take additional mitigation measures?
- Resource assessment: Stakeholders suggested that the RESP online mapping viewer tool should include information on hydraulic height, in addition to existing data on structural height, of existing dams. RESP researchers responded that this is a long-term goal, since that information does not presently exist and would have to be gathered through field measurements.
- Climate change: Stakeholders recommended adding a discussion to the RESP and RIDEM documents about the effects of climate change on river flow and hydropower potential. The RESP team responded to this suggestion by adding Section 3.1.3 of this chapter.

Stakeholders identified several perceived constraints relating to development of low-head hydropower on existing dams in Rhode Island rivers. These included: the complexity and fragmented nature of regulations relevant to the construction of new hydropower facilities on existing dams; the high number of agencies with jurisdiction over various aspects of hydropower projects; the high monetary investment necessary to get a hydropower project up and running; the high cost of doing environmental remediation at existing dam sites; the fact that most existing dams were originally built for mechanical, not electrical, purposes; the unknown or complex ownership status of many dams in Rhode Island; and liability issues surrounding modification of old dams.

Stakeholders also discussed perceived opportunities related to conversion of existing dams to hydropower facilities. Several saw the large number of existing dams in Rhode Island as an untapped opportunity for economic development, and many suggested that hydropower development might also open a window to new environmental opportunities. Specifically, stakeholders saw potential environmental opportunities in devising ways to piggyback on new hydropower developments to improve river conditions and to provide funding for river restoration efforts.

5.2 Rhode Island Hydropower Workshop II

On June 19, 2012, the URI Outreach Center convened a second all-day Hydropower Working Session at URI's main campus. The goal of the workshop was to work with stakeholders and key decision makers to explore the potential for river restoration and low-impact hydropower development to thrive synergistically. Forty people attended the workshop, from a range of state and federal agencies, non-governmental organizations, and other groups. Participants are listed in Ch. 3 Table 5.

Ch. 3 Table 5. Stakeholder Participants at RESP Hydropower Workshops, February 28, 2012 and June 19, 2012.

STATE AGENCIES ▪ R.I. Rivers Council ▪ R.I. Economic Development Corporation (RIEDC) ▪ R.I. Historical Preservation and Heritage Commission (RIHPHC) ▪ R.I. Department of Environmental Management (RIDEM) ▪ Coastal Resources Management Council (CRMC) ▪ Governors' Office ▪ R.I. Office of Energy Resources (RIOER) ▪ R.I. Statewide Planning Program (RISPP)	FEDERAL AGENCIES AND AFFILIATES ▪ National Park Service (NPS) ▪ Federal Energy Regulatory Commission (FERC) ▪ National Marine Fisheries Service (NMFS) ▪ U.S. Fish and Wildlife Service (US F&W)
WATERSHED COUNCILS: ▪ Blackstone River Watershed Council ▪ Wood-Pawcatuck Watershed Association ▪ Woonasquatucket River Watershed Council ▪ Breakwater Preservation Conservancy	NONGOVERNMENTAL ORGANIZATIONS ▪ Conservation Law Foundation ▪ Save the Bay ▪ Narragansett Bay Estuary Program (NBEP) ▪ Trout Unlimited
MUNICIPALITIES ▪ City of East Providence ▪ Town of West Warwick ▪ City of Warwick ▪ Town of Charlestown	CONSULTANTS ▪ Essex Partnership ▪ Mimer Energy

The second RESP Hydropower Workshop was organized at the request of stakeholders who attended the first RESP Hydropower workshop. These stakeholders felt that the State would benefit from further conversation about balancing environmentally sustainable hydropower with river restoration. The second Hydropower Workshop created a neutral forum for participants to discuss whether river restoration and low impact hydro development could occur together in Rhode Island, and if so, what key actions would need to take place to stimulate their joint and mutual advancement. The workshop exercises provided an opportunity to test a more integrated strategy to river systems planning and management where restoration and development are evaluated synchronously, rather than through a piecemeal approach. To facilitate conversation, the URI team identified the following objectives for the workshop:

- Discuss and identify possible criteria for selecting river systems (e.g., river runs, specific sites, etc.) where low impact hydropower development and river restoration could occur synergistically.
- Discuss how these criteria align with the current state strategy/approach for river system management.
- Apply criteria to identify potential river segments where there could be synergistic river restoration and low impact hydro power basins and rivers.
- For these possible areas, discuss and understand the opportunities and challenges of balancing river restoration and developing hydropower.

- For these sites and more generally, define what next steps would be supporting and promoting low impact, mutually supportive restoration and hydropower efforts.

The workshop consisted of three main parts: two breakout activities and a panel presentation. During the first breakout session, participants compiled criteria for selecting ideal sites for both river restoration and low impact hydropower development. The general consensus among participants was that co-location of hydropower and river restoration is a challenging endeavor dependent on highly site-specific considerations, but that it is possible to identify some generally appropriate selection criteria. Notably, each group at the workshop independently settled on a strikingly similar set of criteria. The following list summarizes common criteria proposed by participants for selecting ideal sites for both restoration and hydropower:

- **Dam removal is not an option:** Stakeholders agreed that joint development of hydropower and river restoration is most appropriate in cases where removal of a dam is not an option. Where dam removal is possible, it tends to be the most ecologically beneficial option for river restoration – an option that is clearly not aligned with development of hydropower. Possible indicators that removal of a dam is not feasible include a high degree of urbanization around the dam, presence of flood control structures and/or drinking water supplies, RIDEM designation as a high-hazard dam, and other societal benefits associated with retaining the existing dam structure.

- **Minimal competing uses for flow and water quality:** Stakeholders felt that this precondition might be a useful measure of whether a river system can accommodate provision of energy services in addition to maintenance of ecosystem services.

- **Project is economically viable over the long term:** Stakeholders recommended that hydropower and restoration be considered together only when a proposed new hydropower facility is economically viable. Such projects would be characterized by adequate power resources, feasible interconnection, and above marginal returns.

- **Facility improves environmental conditions over the long term:** Although hydropower can have negative environmental impacts, stakeholders suggested that there may be instances where hydropower could actually provide a mechanism to improve environmental conditions. For example, in cases where hydropower is the only funding source available for restoration, development might be a strategic way to finance new fishways or dam removals.

- **Buy-in:** Stakeholders stressed community engagement as a necessary precondition for selecting sites where hydropower development and river restoration could beneficially occur together. Garnering support from state government, federal agencies, NGO’s, downstream residents, and local businesses represents a crucial step in actualizing any proposed synergy.

After the first breakout session, a panel presentation took place, describing the existing regulatory framework for managing river restoration and low-impact hydropower development and presenting technological innovations useful for encouraging the synergistic development of these two goals. The three panelists, representing RIDEM, USFWS, and hydropower development interests, began by discussing the compatibility of existing hydropower and restoration technologies with the criteria identified during the first breakout session. Panelists provided numerous examples of technological solutions suitable for mitigating or overcoming possible detrimental environmental ramifications associated with hydropower use on a river.

In addition, the panel explored ways in which existing regulatory/management frameworks for hydropower development and river restoration might shape the ability to achieve synergies between the two activities. Panelists stressed that although regulatory compliance can simultaneously be achieved for hydropower development and river restoration projects independently, attainment of higher-level synergistic outcomes may require new approaches to project planning that are both strategic and holistic. Notably, hydropower activities and river restoration projects must currently obtain many of the same authorizations from many of the same agencies (see Ch. 3 Table 4 for a comparison of Federal, State, and local regulations applying to permitting of hydropower and river restoration activities); a strategic approach might involve streamlined permitting of both activities at once.

Lastly, panelists described their perceptions of the opportunities and barriers related to achieving synergy between hydropower development and river restoration. This description drew on examples from other states showing how thoughtful hydropower project relicensing agreements have led to beneficial environmental and economic outcomes.

In the second breakout session, workshop attendees worked together to envision how the criteria identified in during the first breakout session could be applied to specific locations in Rhode Island. This thought exercise served to elucidate what a synergistic approach to river restoration and hydropower might look like on the ground. Each group selected a case study area and used the RESP hydropower online map viewer to identify opportunities and challenges related to the co-location of hydropower and restoration in its chosen area. Case study areas included the Blackstone River, the Pawtuxet River, and the Ten Mile and the Woonasquatucket Rivers (considered as a single area).

Each group also pondered the steps necessary to precondition the concurrent development of hydropower and river restoration. Participants recommended the following possible measures:

- **Improve existing hydropower:** Begin by finding ways to improve the efficiency and operations of existing hydropower. There are known opportunities to increase generation while providing for more consistent flows at existing hydropower sites.

- **Expand future planning:** Develop watershed-scale “Comprehensive Plans”. These plans would be filed with FERC and would formalize basin-wide strategies for restoration and hydropower on Rhode Island rivers. Development and restoration efforts would be required to adhere to the principles identified in these plans. Plans could include novel concepts advancing a systems management context, such as offsite mitigation for hydropower projects or evaluation of cumulative impacts of multiple projects (i.e. flows, water quality, fisheries, aesthetics and recreational/cultural/historic resources, etc). Watershed planners might also contemplate inclusion of "investment portfolios" showing potential projects considered economically feasible; this approach could be used to facilitate package development of multiple sites at once.

- **Fine-tune permitting procedures:** Reach a settlement agreement to cover environmental and mitigation requirements for multiple sites at once, in order to produce higher efficiency during the FERC licensing process. Adopt a funding mechanism to permit possible offsite mitigation.

- **Streamline management:** Consider formalizing a mechanism for coordinating and managing the operations of multiple plants on a river.

- **Take legislative action:** Clarify a price and schedule for hydropower in the Distributed Generation (DG) program. The DG program in its current form calls for projects to begin producing power on an accelerated timeline, effectively excluding hydropower due to the protracted length of the FERC licensing process.

- **Continue the stakeholder process:** Establish a post-RESP process to continue involving stakeholders in a conversation about joint planning and management for hydropower and river restoration. Involve the energized and knowledgeable stakeholder communities that already exist in each watershed. Bi-state coordination may be beneficial in the case of Ten Mile and Blackstone.

5.3 Additional Research Needs Identified by Stakeholders

During both hydropower stakeholder workshops and throughout the RESP process, hydropower and river restoration stakeholders identified several knowledge gaps relevant to the development of hydropower on Rhode Island rivers. This section presents a list of priorities for future research and discussion. Some of these pending questions can be answered through continued conversation among policy makers and stakeholders; others may benefit from use of future hydropower projects as living laboratories to help illuminate lingering unknowns.

- **Technological innovation**: Hydropower technology for low-head applications is evolving. Future hydropower research in Rhode Island should explore emerging hydropower technologies that promise a lower impact to ecosystems and water quality than present mainstream technologies.

- **Alternative hydropower technologies**: Since pursuing full-fledged new hydropower facilities requires large investments, it may be more feasible to first explore the renewable energy production benefits that could be attained by improving the efficiency of existing hydropower plants by incorporating alternative hydropower technologies.

- **Fish passage restoration success rates**: Improved metrics for assessing progress towards fishway restoration goals are needed to inform mitigation requirements attached to hydropower permits and to advance integrated restoration programs. Additional data is needed on how hydropower affects fish passage at sites where restoration efforts and hydropower development coincide.

- **Development of hydropower on state-owned dams**: Several dams in Rhode Island exist on state-owned land. Presently, it is unclear whether these dams should be opened up to hydropower development through sale, lease, or another method.

- **Legal treatment of existing fish passage restoration projects**: In recent decades, many dams in Rhode Island have received modifications to make them usable by diadramous fish for upstream passage. It is presently unclear how these existing fish passage modifications would be treated in the event that these dams undergo further modification in conjunction with hydroelectric development.

- **Dam safety requirements:** Many of Rhode Island's 742 dams do not serve their original purpose and pose a public safety liability. While RIDEM is required by the Dam Safety Program to visually inspect every dam in the state. RIDEM does not have the staff or the resources to make full engineering analyses of the structural integrity of each dam (Dam Safety Report, 2010 pg 25). Hydropower development may represent a strategy to create clear ownership status and revenue streams for partially addressing this statewide dam management issue.

6. References

Association of State Dam Safety Officials. 2012. Dam Safety: A National Concern. Available online at: http://www.damsafety.org/news/?p=d42cd061-cae2-4039-8fc6-313975f97c36. Last accessed March 31, 2012.

Bear, Katherine. 2007. Celebrate Clean Water: The Clean Water Act's Sleeper Provision—Section 401. Available online at: http://www.americanrivers.org/newsroom/blog/the-sleeper-provision-section-401.html. Last accessed April 9, 2012.

Blackstone Valley Tourism Council. The Green Visitor Guide: Blackstone Valley, Rhode Island. Available online at: http://www.blackstonevalleytourismcouncil.com/greenguide.pdf. Last accessed April 9, 2012.

Blackstone River Valley National Heritage Corridor Commission. 1998. Natural Resources Inventory and Assessment: The Blackstone River Valley. Available online at: http://www.nps.gov/blac/naturescience/upload/NRInv.pdf. Last accessed April 10, 2012.

Burns, DA., J. Klaus, and M.R. McHale. Recent climate trends and implications for water resources in the Catskill Mountain Region, New York, USA. *Journal of Hydrology* 336: 155-170.

CLF (Conservation Law Foundation) 2010. Blackstone River Watershed Hydropower Feasibility Study, Phase I Report. Available online at: http://www.essexpartnership.com/wp-content/uploads/2011/06/Blackstone-River-Watershed-Hydropower-Phase-1-Feasibility-Study_-Final_12-28-10_v2.pdf. Last accessed April 15, 2012.

Edwards, Phil. RIDEM Division of Fish and Wildlife. Personal Communication. April 2012.

Energy Information Administration. 2012. State Renewable Electricity Profiles 2010. Available online at: http://www.eia.gov/renewable/state/pdf/srp2010.pdf . Last accessed May 3, 2012.

Essex Partnership. 2010. Pawtuxet River Watershed Hydropower Feasibility Study Phase 1 Report. Available online at: http://www.essexpartnership.com/wp-content/uploads/2011/06/Blackstone-River-Watershed-Hydropower-Phase-1-Feasibility-Study_-Final_12-28-10_v2.pdf. Last accessed April 16, 2012.

Essex Partnership. 2011. Ten Mile River Hydropower Feasibility Study. Available online at http://www.essexpartnership.com/wp-content/uploads/2011/10/FINAL-E-PROV-RPT-w-APPs_5-11.pdf. Last accessed April 16th, 2012.

Essex Partnership. 2012. Northern Rhode Island Municipal Energy Collaborative. Available online at: http://www.essexpartnership.com/northern-rhode-island-municipal-energy-collaborative/collaborative. Last accessed April 15, 2012.

FERC (Federal Energy Regulatory Commission) and Advisory Council on Historic Preservation. 2002. Guidelines for the Development of Historic Properties Management Plans For FERC Hydroelectric Projects. Available online at: http://www.ferc.gov/industries/hydropower/gen-info/guidelines/hpmp.pdf. Last accessed April 9, 2012.

FERC (Federal Energy Regulatory Commission) 2012. Licensing, updated April 9, 2012. Available online from: http://www.ferc.gov/industries/hydropower/gen-info/licensing.asp. Last accessed April 14, 2012.

Governor's Task Force on Dam Safety and Maintenance. 2001. Final Report. Available online at: http://www.dem.ri.gov/programs/benviron/compinsp/pdf/damrep01.pdf. Last accessed March 31, 2012.

Handbook for Hydroelectric, supra note 6, at 6-2. Fed. Energy Regulatory Comm'n, Handbook for Hydroelectric Project Licensing 2-1 (2004) available at: http://www.ferc.gov/industries/hydropower/gen-info/handbooks/licensing_handbook.pdf

Harrison, G. P. and H. W. Whittington. 2002. Vulnerability of hydropower projects to climate change. *IEE Proceedings Generation, Transmission & Distribution* 149(3): 249-255.

Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe. 2007. Past and Future Changes in Climate and Hydrological Indicators in the US Northeast. *Climate Dynamics* 28: 381-407.

Hodgkins, G.A., R.W. Dudley, T.G. Huntington. 2003. Changes in the timing of high river flows in New England over the 20th century. *Journal of Hydrology* 278: 244-252.

IPCC (Intergovernmental Panel on Climate Change). 2007a. The AR4 Synthesis Report. Available online at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html Last accessed March 6, 2012.

Lenderink, G. and E. Van Meijgarrd. 2008. Increase in hourly precipitation extremes beyond expectations from temperature changes. *Nature Geosciences* 1: 511-514.

LIHI (Low Impact Hydropower Institute). 2011. Certification Handbook, Including Materials Required in Applying for Certification. Available online at: http://www.lowimpacthydro.org/assets/files/LIHI%20HandbookDecember%202011%281%29.pdf. Last accessed April 13, 2012.

LIHI (Low Impact Hydropower Institute). 2012. LIHI Certificate #11 - Pawtucket Project, Blackstone River, Rhode Island, (FERC #3689). Available online at: http://www.lowimpacthydro.org/lihi-certificate-11-pawtucket-project-blackstone-river-rhode-island-ferc-3689.html. Last accessed April 13, 2012.

McClain, Serena, Stephanie Lindloff, and Katherine Baer. 2008. Dam Removal and Historic Preservation: Reconciling Dual Objectives. Available online at: http://www.ncshpo.org/current/pdfresources/Dam_Removal_and_Historic_Preservation.pdf. Last accessed April 9, 2012.

Miyake, Misaki. 2008. Tourism and the Local Business Community in Small Cities and Towns: A Qualitative Study of the Blackstone Valley, Rhode Island. Thesis Submitted to Boston University in partial fulfillment of the requirements for the degree of Master of Science in Administrative Sciences. Available online at: www.sustainabletourismlab.com/thesis.doc. Last accessed April 9, 2012.

NATHPO (National Association of Tribal Historic Preservation Officers). 2012. THPO Contact List. Available online at: http://www.nathpo.org/THPO/state_list.htm. Last accessed April 9, 2012.

National Grid, 2012. Net Metering in Rhode Island. Available at: http://www.nationalgridus.com/narragansett/home/energyeff/4_net-mtr.asp. Last accessed May 20, 2012.

National Wild and Scenic Rivers System. 2012. National Wild and Scenic Rivers. Available at: http://www.rivers.gov. Last accessed April 10, 2012.

NCSHPO (National Conference of State Historic Preservation Officers). 2012. State Information and SHPO List. Available online at: http://www.ncshpo.org/find/index.htm. Last accessed April 9, 2012.

NOAA 2012. State Coastal Zone Boundaries. Available online at: http://coastalmanagement.noaa.gov/mystate/docs/StateCZBoundaries.pdf. Last accessed April 9, 2012.

Pascoag Reservoir/Echo Lake Dam Management District. 2010. Bylaws of the Pascoag Reservoir/Echo Lake Dam Management District. Available online at: http://prdmd.org/documents/PRDMD%20BYLAWS%20FINAL%20Approval%202-13-2010.pdf. Last accessed April 29, 2012.

Rhode Island Habitat Restoration Portal. 2012. Anadromous Fish Habitats. Available online at: http://www.edc.uri.edu/restoration/html/intro/fish.htm. Last accessed March 31, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2002. Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams. Available online at: http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/riap2002.pdf/. Last accessed April 14, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2005. Amendment to Section 7.14.2 of Part VII of the Rhode Island Marine Fisheries Regulations. Available online at: http://www.dem.ri.gov/pubs/regs/regs/fishwild/fishamnd.htm. Last accessed April 14, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2006. Amendment to Section 7.20 of Part VII of the Rhode Island Marine Fisheries Regulations. Available online at: http://www.dem.ri.gov/pubs/regs/regs/fishwild/fishamnd.htm. Last accessed April 14, 2012.

RIDEM (Rhode Island Department of Environmental Management). Rules and Regulations for Dam Safety. 2007. Available online at: http://www.dem.ri.gov/pubs/regs/regs/compinsp/dams07.pdf. Last accessed April 29, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2010a. Annual Report to the Governor on the Activities of the Dam Safety Program. Available online at: http://www.dem.ri.gov/programs/benviron/compinsp/pdf/damrpt11.pdf. Last accessed October 1, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2010b. Streamflow Depletion Methodology. Available online at:

http://www.watershedcounts.org/documents/StreamFlowDepletionMethodology.pdf. Last accessed April 29, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2011a. Dam Information Update Spreadsheet.

RIDEM (Rhode Island Department of Environmental Management). 2011. State of Rhode Island 2010 303(d) List of Impaired Waters. Available online at: http://www.dem.ri.gov/pubs/303d/303d10.pdf. Last accessed April 9, 2012.

RIDEM (Rhode Island Department of Environmental Management). 2012. Draft Management Guidance on Siting Considerations for Development of New Hydropower Facilities.

Rhode Island Rivers Council. 2012a. Pawtuxet River Watershed. Available online at: http://www.ririvers.org/wsp/Watersheds/PawtuxetRiverWatershed.htm. Last accessed April 16, 2012.

Rhode Island Rivers Council. 2012b. Ten Mile River Watershed. Available online at: http://www.ririvers.org/wsp/Watersheds/TenMileRiverWatershed.htm. Last accessed April 16, 2012.

Rhode Island Rivers Council. 2012c. Wood-Pawcatuck River Watershed. Available online at: http://www.ririvers.org/wsp/Watersheds/WoodPawcatuckWatershed.htm. Last accessed April 16, 2012.

Rhode Island Rivers Council. 2012d. Woonasquatucket River Watershed. Available online at: http://www.ririvers.org/wsp/Watersheds/WoonasquatucketRiverWatershed.htm. Last accessed April 16, 2012.

Save the Bay. 2012. Fish Runs. Available at: http://www.savebay.org/Page.aspx?pid=257. Last accessed April 14, 2012.

Serreze, Mary. 2010. Dueling Engineers: Can Micro-Hydro Save the Dam? Northampton Media. Published May 15, 2010. Available online at: http://northamptonmedia.com/blog/05/15/2010/dueling-engineers-can-micro-hydro-save-the-dam/. Last accessed April 9, 2012.

Sharpe, Sue. 2008. Historic Dam may be reused for hydroelectric. Preserve NJ. Published April 2, 2008. Available online at: http://preservationnj.wordpress.com/2008/04/02/historic-dam-may-be-reused-for-hydro. Last accessed April 9, 2012.

Stillwater Sciences, Confluence Research and Consulting, and Heritage Research Associates, Inc. 2006. Scientific approaches for evaluating hydroelectric project effects. Prepared by Stillwater Sciences, Arcata, California, for Hydropower Reform Coalition, Washington, DC.

State Planning Council. 1990. Element 13: Heritage and Land Management Plan for the Blackstone River Valley National Heritage Corridor. Available online at: http://www.planning.ri.gov/sgp/pdf/131.pdf. Last accessed April 9, 2012.

Town of Exeter. 2007. Boone Lake District Ordinance. Available online at: http://boonelakeri.org/pdfs/boone_lake_dam_district_ordinance.pdf. Last accessed April 29, 2012.

USACE and FERC. 2011. Memorandum of Understanding between United States Army Corps of Engineers and the Federal Energy Regulatory Commission on Non-federal Hydropower Projects. Available online at: http://www.ferc.gov/legal/maj-ord-reg/mou/mou-usace.pdf. Last accessed April 8, 2012

USDOE (United States Department of Energy). 1995. U.S. Hydropower Resource Assessment for Rhode Island. Available online at: http://hydropower.inl.gov/resourceassessment/pdfs/states/ri.pdf. Last accessed April 14, 2012.

USEPA (United States Environmental Protection Agency). 2012. Waste Site Cleanup and Reuse in New England. Available online at: http://www.epa.gov/region1/cleanup/resource/findnesites.html. Last accessed April 15, 2012.

Whittington, H.W. & Gundry, S.W. 1998. Global Climate Change and Hydroelectric Resources. *IEE Engineering Science & Technology Journal*..

Woonasquatucket Watershed Council. 2012. About the Watershed. Available online at: http://www.wrwc.org/overview.php. Last accessed April 16, 2012.

RENEWABLE ENERGY SITING PARTNERSHIP

CHAPTER 4. RI ENERGY.ORG

Table of Contents

List of Figures

List of Tables

1. Introduction

The Renewable Energy Siting Partnership evaluated potential opportunities and impacts of land-based renewable energy development in the State of Rhode Island. The information gathered through the RESP—based on research, expert input, and stakeholder involvement—provides a foundation for informing sound policy decisions on the state and local level. In order to sustain this capacity for promoting data-driven energy decision-making, the RESP developed the first Rhode Island-specific website housing energy data, resource mapping and siting tools, and information for citizens, businesses, and government officials. This energy information clearinghouse is called RI Energy.org. By providing Rhode Island decision-makers and communities with easy access to a centralized source of energy information, RI Energy.org will pave the way for the Ocean State to capture a smarter and brighter energy future.

1.1 Objectives

RI Energy.org was initially conceived in response to a recognition that Rhode Islander residents, communities, and decision-makers lacked easy access to relevant information regarding energy. Therefore, the primary objective of this site is to make Rhode Island state and municipal energy data available to the public in a centralized and coherent fashion. An ultimate ambition of the website is to set the stage for future data-driven energy policy by making a comprehensive baseline energy dataset available to decision-makers. The contents of the site include:

1. Map viewers & siting decision support tools
2. Energy information and data, centralized and publicly available (RI Energy “Data Center”)
3. Other information and resources on Rhode Island energy

2. Gathering the Data

The RESP team took several steps as a matter of due diligence to inform the conceptual design and development of RI Energy.org. RESP researchers conducted a data needs assessment, catalogued existing information, and finally, surveyed similar online tools and databases currently used in other states. The following tasks were completed:

1. Assessment of data needs and potential uses
2. Assessment of existing data for Rhode Island
3. Assessment of energy data projects elsewhere in the United States

2.1 Assessment of Data Needs and Potential Uses

The Stakeholder Process & Public Engagement Chapter of the RESP report details the efforts on behalf of the RESP to solicit input on data needs from the general public, local and state agencies, advocacy organizations and industry, and other stakeholder audiences. Through the stakeholder process, the RESP team identified issues and assessed needs of interest to those engaged in energy work in Rhode Island. The interactions with stakeholder groups, both general and specific (e.g. Municipal Working Group, Hydropower Working Group), helped inform which datasets should be gathered for inclusion in RI Energy.org.

Based on the participants in the RESP stakeholder process, the expected audiences of RI Energy.org are local, municipal, and state governments, academic institutions, advocacy groups, and the general public. Secondary users are likely to be in private industry and quasi-public agencies associated with economic development, renewable energy, or utilities.

The primary data needs of these expected users informed the data collected and incorporated into the final element. For the general public, this may include information on incentives, rebates, and resources available to support implementation of efficiency or clean energy measures at a residency or business. The general public may also be interested in the basic facts concerning the effects of developing solar, wind, and hydropower projects throughout the state, including ecological, human, or economic impacts of these projects. Other users such as policy makers and government agencies may need access to baseline energy datasets to evaluate the potential economic and environmental benefits of clean energy investment at different economies of scale. Finally, for many of the expected site users, data on the requirements, siting criteria and impacts of renewable energy systems will help guide implementation at the town level.

General public and Outreach	• Information to help educate and promote smart energy decisions
Policymakers	• Single source for information regarding State's energy
Towns and Communities	• Decision support tools to site renewable energy projects
Academics and Industry	• Current and historical data sets readily available for research and analysis

Ch. 4 Figure 1. RI Energy Audiences.

Through the stakeholder process, and through a background review, the RESP team determined the body of data deemed necessary to describe Rhode Island's current energy systems and to inform adapting these energy systems based on future needs and goals. The final data contents of RI Energy.org include:

1. Consumption (e.g. MWh)*
2. Price (e.g. $/gal)*
3. Generation (e.g. MWh)*
4. Facilities/Infrastructure/Constraints (e.g. Power Plants, Transmission Lines, Siting Constraints)*
5. Emissions (e.g. CO_2)*

*Sortable by fuel type/energy source (fossil, renewable, efficient, etc.), sector (residential, commercial, industrial, etc.), and geographical area (state, municipality, ZIP code, etc.) as appropriate.

The RESP team chose to provide several means of visualizing the data, in order to optimize an intuitive design, facilitate public understanding of the data, and provide ease of use. The Rhode Island energy data on RI Energy.org are displayed:

1. Geospatially
2. Graphically
3. Textually
4. Downloadable (pdf, tabular, etc.)

2.2. Assessment of Existing Data for Rhode Island

The RESP generated a variety new Rhode Island-specific data: from the potential opportunities and impacts of land-based renewable energy development to historical price, consumption, generation, and emissions data. Many datasets and informational resources gathered by the RESP also represented a body of existing knowledge. The RESP team sought to collect and aggregate this wealth of existing data, which previously was dispersed throughout separate silos of disparate government agencies, municipal entities or private sector companies. The RESP organized and centralized this information to make it accessible to the public.

The RESP team worked with multiple project partners to identify important existing data. Through these collaborations, the RESP harvested such diverse data as dam and landfill locations and specs; electrical and gas consumption; and information on historical districts and locations. In particular, fruitful partnerships were cultivated with the following entities, who supplied key existing datasets to the RESP:

- Rhode Island Department of Environmental Management
- Rhode Island Statewide Planning Program
- Rhode Island Historical Preservation and Heritage Commission
- Department of Defense, Naval Station Newport
- National Grid
- U.S. Energy Information Administration
- Rhode Island Municipalities

The existing data helped feed the RESP analysis, and provided a foundation for developing the Rhode Island Energy Data Center on RI Energy.org.

2.3 Assessment of Energy Data Projects Elsewhere in the U.S.

The RESP team conducted a survey of existing energy data and mapping websites developed by other states that could provide models for RI Energy.org. The goal was to leverage best design, features, and functionalities in order to make Rhode Island's energy website a superior example of an online state energy website. RI Energy.org is the first of its kind to blend renewable energy mapping tools with a centralized energy database. Examples were sought that captured both of these end goals. The Renewable Energy Atlas of Vermont was identified as a model example of a mapping/siting tool and the New Jersey Energy Data Center provided an instance of how energy data might be compiled, organized and presented.

2.3.1 Renewable Energy Atlas of Vermont

The Renewable Energy Atlas of Vermont was the first tool in the U.S. of its kind to allow users to identify, analyze, and visualize existing and potential sites for multiple types of energy projects. The site was developed as part of a collaborative effort between the Vermont Sustainable Jobs Fund (VSJF), Vermont Center for Geographic Information, Fountains Spatial, and Overit Media based out of Albany, New York. It was funded by the U.S. Department of Energy, the Vermont Clean Energy Development Fund, Vermont Community Foundation, and Green Mountain Coffee Roasters. The goal of the Renewable Energy Atlas was to let users to assess possibilities for renewable energy and efficiency projects in their town and understand how these projects would affect energy planning and policies. It targets an audience consisting of the general public, town energy committees, Clean Energy Development Fund, educators, planners, policy-makers, and businesses. The tool is intended to help decision-makers evaluate options to increase the amount of non-carbon-emitting sources of energy in the state's energy portfolio via the informed and strategic siting of efficiency measures and renewable projects.

The resulting decision-support tool is a GIS-based system that allows its users to select a location and analyze options for wind, solar, hydroelectric, geothermal, and biomass generation as well as efficiency projects. The mapping interface completes an assessment of the potential energy project, provides the information necessary to interpret the results of the analysis, and the option to save the map and results as a PDF or URL. The site allows users to work with one energy option at a time and determine the percentage of a given area that is usable in accordance with multiple siting criteria restrictions and available financing options.

The tool displays the steps taken to complete an analysis including calculations, assumptions, how the data was collected, and from which resources. Site developers used a variety of sources for each data layer appearing on the interactive map. Site users can view these original sources along with a complete page of metadata for each data layer. Many of the layers were created from ESRI ArcGIS Online basemaps and services and the Vermont Center for Geographic Information. Additional data sources include True Wind Solutions, LLC and the Massachusetts Technology Collaborative for wind speed maps, the Water Quality Division, River Management Section, and Wetlands Section of the Vermont Department of Environmental Conservation (DEC) for data related to wetlands and hydro dams, the Vermont Agency of Natural Resources, and the Vermont Fish and Wildlife Department. The data collected from these sources is updated frequently in the database and the site documents the date of the most recent update for each data layer.[1]

2.3.2 New Jersey Energy Data Center

The New Jersey Energy Data Center provided a model for energy data and trend visualization. The State of New Jersey Energy Data Center was funded by the New Jersey Board of Utilities to develop a site that would serve as a data collection and processing tool for its users. The site targets policy makers, businesses, academics, and the general public in the State of New Jersey by providing data and analyses for energy-related policy decisions. The intuitive design is intended to provide ease of navigation and to promote a general understanding of the data. The site also provides data for different types of analyses in the New Jersey Energy Master Plan or modeling in the Rutgers Econometric Model.

Users are able to choose from different categories—petroleum, natural gas, and electricity utilities—and view consumption, price, and emissions data in table or graph format. The site also provides a section describing the New Jersey Clean Energy Program, the state's Energy Master Plan, and economic and demographic data from the U.S. Census Bureau and the U.S. Bureau of Labor and Statistics. Besides table and graph formats, the site offers static maps displaying information such as demographic data, heating fuel breakdown, summer energy capacity, and annual MWh usage by county. The site also provides an "Energy 101" page with background energy information, facts, and basics for beginners.

Site developers based the New Jersey Energy Data Center on the Energy Information Administration (EIA) site, which was a primary source for data presented on the site. Other data sources include the New Jersey Clean Energy Program, U.S. Bureau of Labor Statistics, and PJM, the regional transmission organization for New Jersey. Data needs were identified principally through meetings with the New Jersey Board of Public Utilities, who funded the project. The site was originally created by a Center for Energy, Economic, and Environmental Policy (CEEEP) employee alongside the Board of Public Utilities with the goal of providing up-to-date energy information for the state. As of the time of this writing, the site is now maintained by a student programmer.[2]

2.3.3 Other Examples

Other major databases informing the design of RI Energy.org include the California Energy Commission Energy Almanac, the United States Energy Information Administration

[1] Renewable Energy Atlas of Vermont. http://www.vtenergyatlas.com/
[2] New Jersey Energy Data Center. http://www.njenergydatacenter.org/

(EIA), International Energy Association (IEA). These offer public information on fuel pricing, consumption, and production. The CEC Energy Almanac provides a wealth of data related to energy use in California online and available for download. The U.S. EIA collects and analyzes energy information that covers production, demand, imports, exports, and pricing. The IEA gathers similar data but is international in scope and provides support for research to improve global energy security and economic development.

3. RI ENERGY.ORG CONTENTS

3.1 Map Viewers & Siting Decision Support Tools

The RESP developed an interactive GIS interface to facilitate assessment of energy resource potential and possible impacts and constraints of developing different energy resources. Separate viewers were developed for each of the following energy resources: wind, hydro, solar, and efficiency. The purpose of these tools was not to identify the best sites for development in the state, but to provide a resource for municipalities, potential developers, and residents seeking to understand potential siting considerations at a given location.

RESP viewers were developed through compilation of a number of map layers, each one representing a certain aspect relevant to each particular energy resource. The RESP map viewers enable interested parties to visualize these map layers individually or in combination, and to manipulate them in order to view select variables of interest.

A full description and visual displays of the layers provided in each viewer may be found in Appendix A. For more information on the RESP research and stakeholder process used to inform the layers in each viewer, please refer to the respective chapter in Volume I of this report or associated Technical Reports in Volume II of this report.

Additionally, a Wind Siting Tool was developed to specifically address the impacts of land-based wind turbine development. Details concerning this tool may be found in Appendix A as well.

3.2 RI Energy Data Center

The RESP established an RI Energy "Data Center", located on the RI Energy.org website, to house all the data collected by the RESP and represented in the viewers. The goal of the Data Center was to provide a comprehensive, publicly accessible collection of Rhode Island-specific energy datasets. In addition to renewable energy siting constraints data, information was gathered on various fuels and energy sources used in Rhode Island and their historical prices, consumption, generation, associated generation facilities/infrastructure, emissions, and other relevant information.

The "Data Center" contains both a database of all the energy data collected through the RESP, as well as a Map Gallery to provide quick viewing of all the maps produced by the RESP. Downloadable files found in the Data Center correspond to the information visually represented in each Map Viewer and graphically represented in each Chart Viewer on RI Energy.org. Therefore, users who work with a map viewer to analyze renewable energy resources or users who examine a chart displaying a certain trend can then access the corresponding raw data to manipulate for their own purposes.

Fossil fuel data on RI Energy.org was gathered independently from the renewable energy data. Technical documentation and a full summary of the electricity and fuel data collected may be found in Appendix B.

3.3 Additional Resources

RI Energy.org also provides general information and resources regarding energy in Rhode Island. Some of these resources are geared towards members of the general public; others toward academics or student researchers, still others toward local or state officials. Users new to energy issues might navigate to the "Energy 101" page to learn more about Rhode Island energy's landscape or to be directed to educational resources on energy issues. Other users might visit the "Programs & Policies" page looking for incentives to implement energy solutions in their homes or businesses. Some users might browse the portal of energy-related publications under the "Papers" page to find a resource to further explore a subject of their interest. Still other users may be curious about what agencies, organizations, and partnerships are involved in energy issues in the state; those visitors would access the "Who's Who" page.

4. APPENDIX A: MAP VIEWER LAYERS

4.1 Appendix A1: Wind

The Wind Viewer provides a geospatial platform for visualizing the potential opportunities and constraints associated with siting wind turbines in Rhode Island. For more information on wind power in Rhode Island and the RESP research and stakeholder process used to inform this viewer, please refer to the Wind Chapter in Volume I of this report or associated Technical Reports in Volume II of this report. The following layers were compiled for the wind viewer (see Appendix A to view visual displays of each map layer):

1. Wind Resource
2. Federal Aviation Administration (FAA) restricted areas
3. Population density
4. Wetlands
5. Water bodies
6. Impervious surfaces
7. Conservation lands
8. Areas with threatened or endangered avian species
9. Bird habitats
10. Communication towers
11. Historical sites
12. Ecological Land Units (ELUs)
13. Background noise level

Ch. 4 Table 1. Wind Viewer/Siting Tool Layers.

Layer	Siting Consideration/Issue	Description	Data source
Federal Aviation Administration (FAA) restricted areas	The Federal Aviation Administration (FAA) requires a setback between airports and any structure measuring over 200 ft (61m). The distance of this setback varies according to the size of the airport	This layer shows areas where height restrictions associated with the FAA may need to be considered. This layer was created by examining the height restrictions around the following Rhode Island airports: T.F. Green International Airport, Block Island State Airport, Westerly State Airport, Quonset State Airport, North Central State Airport, Newport State Airport, and Richmond Airport.	The FAA provides online siting tools to help determine if an FAA ruling is required for a project (see https://oeaaa.faa.gov/oeaaa/external/portal)
Population Density	Residential population density may be an important metric when considering the impacts of wind turbine noise, shadow flicker, safety concerns, and other potential impacts.	This layer represents population density by mapping standard deviations above/below the mean R.I. population density of 1018 people/mile^2. Areas shaded in orange and red represent areas of high population density, which may require additional siting considerations to minimize any impacts to surrounding residents.	Data from U.S. Census 2010; Layer obtained from the Rhode Island Geographic Information System (RIGIS).
Wetlands, with 50-ft (15-m) buffer zones	Wetlands are considered a particularly valuable and irreplaceable habitat, and require special consideration in the wind turbine siting process.	This layer shows the location of wetlands (freshwater and coastal?) The layer also incorporates a 50 foot buffer around each wetland area, to represent the setback recommended by Paton et al. (2012).	RIDEM
Water bodies, rivers and large streams, with 100 ft (30 m) buffer zones	Water bodies represent hard constraints, where wind turbines cannot be sited.	This layer shows the lakes, rivers, and streams that are found throughout Rhode Island, with 100 ft (30 m) buffer zones around them.	RIGIS
Impervious surfaces	Impervious surfaces represent hard constraints, where wind turbines cannot be sited.	This layer shows highways, roads, parking lots, and other impervious surfaces in Rhode Island.	RIGIS
Conservation lands	Development of a wind power facility in or near state, federal, and NGO protected areas may complicate the permitting process, unless the state, federal, or NGO owner/manager of the land is also the developer of the wind facility.	This layer shows state, municipal, and NGO lands designated for protection.	RIGIS
Areas with threatened or endangered avian species, with buffer zones	Areas of importance to vulnerable bird populations represent areas where wind energy development may be inappropriate (Paton *et al*. 2012)	This layer shows areas with previous sitings of four threatened or endangered bird species, with the buffers prescribed by Paton et al (2012): ▪ American Oystercatcher (500m; 0.3 miles) ▪ Bald Eagle (1 mile; 1.6 km) ▪ Least Tern (1 km; 0.6 miles) ▪ Roseate Tern (1 km; 0.6 miles)	Paton *et al*. (2012)

Bird habitats, with buffers: Grassland; Forests; Shrubs	Grassland, forest, and shrubland habitats are important for vulnerable bird species, and some of these habitats are declining in Rhode Island. These habitats represent areas where wind energy development may be deemed inappropriate for conservation reasons (Paton et al. 2012)	These layers show patches of grassland greater in size than 3 acres, with a 100-m (328-ft) buffer around each patch; forests greater than 100 acres; and shrub habitat greater than 5 acres, with a 100-m(328-ft) buffer around each patch.	Paton *et al*. (2012)
Communication Towers	Consideration of the proximity of a proposed wind turbine to existing communication towers may help to minimize any potential interference effects.	This layer shows the current location of all existing communication towers in Rhode Island.	RIGIS
Historical state and federal sites, areas, and cemeteries	Rhode Island's historical and cultural areas possess important heritage value, and many are protected by law. These sites and areas represent areas where wind energy development may be inappropriate and/or illegal. Cemeteries should be viewed as a hard constraint where development of wind turbines cannot take place.	This layer shows historic districts and buildings listed in the National Historic Register. In addition, this layer includes a preliminary dataset representing the approximate locations of historical cemeteries registered with the Rhode Island Advisory Commission on Historical Cemeteries.	RIGIS
Ecological Land Units (ELUs)	Ecological Land Units (ELUs) represent a biodiversity index that may help to identify areas of special ecological importance that should not be disturbed. ELUs are calculated by counting the number of different habitat types found within a 1,500-m (0.9-mile) radius of each point on the map.	This layer shows ELU values across Rhode Island. ELU values were assigned according to a 30x30-meter (98x98-ft) grid.	The Nature Conservancy Rhode Island Chapter and Rhode Island Environmental Data Center
Background noise level (land use, highways)	Ambient noise plays an important role in shaping the effect of wind turbine noise on the surrounding population. Where ambient noise levels are high, wind turbine noise is less noticeable.	This layer shows modeled ambient noise levels created using land use data and the locations of busy highways to predict sound levels.	URI Department of Ocean Engineering

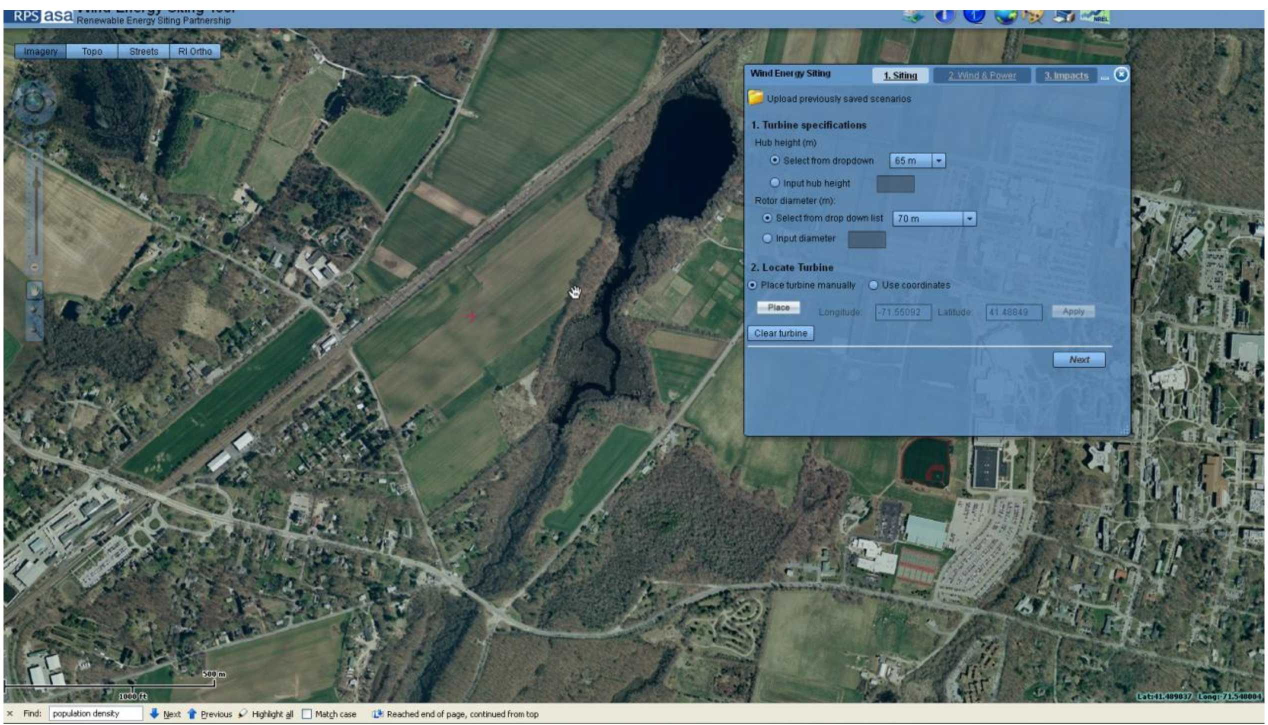
4.2 Appendix A2: Wind Siting Tool

Drawing on the wind map viewer layers, the RESP developed several web-based tools to allow users to visualize how a proposed project site and surrounding areas may be impacted by structural failure, noise, and shadow flicker.

This section presents an overview of the capabilities and functions of the tool. The description that follows adheres to the same structure employed in the siting tool website. The tool can be viewed via three tabs: (1) siting; (2) wind and power; and (3) impacts (see Ch. 4 Figure 2). The functionality of each of these tabs is described below.

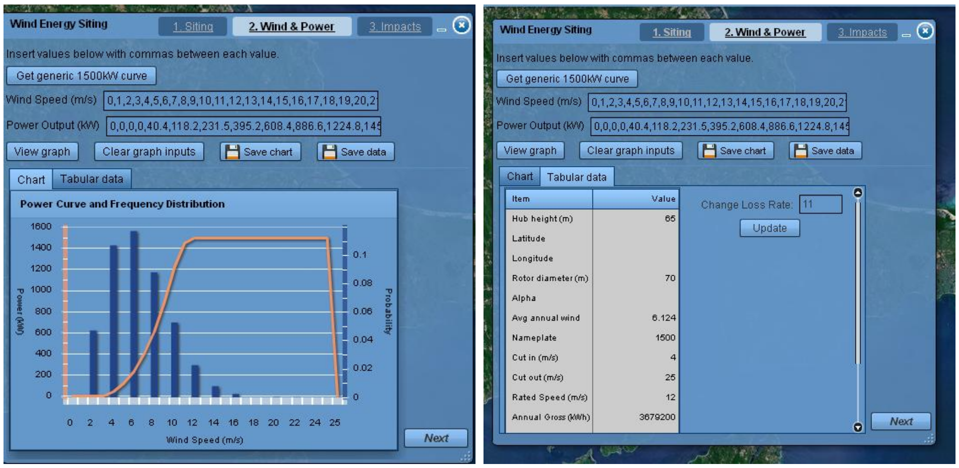
Ch. 4 Figure 2. Wind Energy Siting Tool Tabs Format

Siting Users can input the specific location of a hypothetical turbine using latitude and longitude coordinates, or by selecting a site on the map. Once a user has chosen a site, the tool prompts the user to select the size of the hypothetical turbine (see Ch. 4 Figure 3). This information is necessary for performing the analysis provided in the other two tabs (Wind & Power and Impacts). The siting tool marks the spot of the hypothetical turbine with a red cross.



Ch. 4 Figure 3. Siting Tab of the Wind Siting Tool.

Wind & Power The purpose of the Wind & Power tab is to allow users to assess the amount of power that could be produced at a given location. Based on the specifications of the turbine provided by the user, the tool creates a power curve showing the frequencies of different wind speeds at the site (Ch. 4 Figure 4).



Ch. 4 Figure 4. Wind Siting Tool- Turbine Specification and Power Analysis Capabilities.

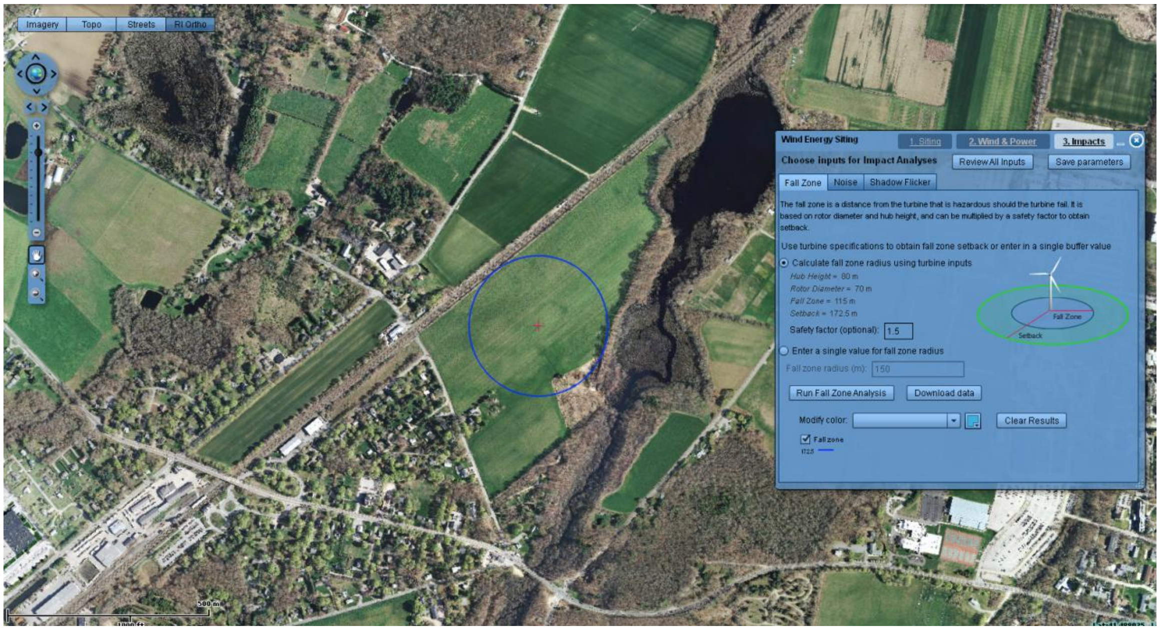
Impact The Impact Tab allows users to view examples of safety setbacks and to observe the predicted zones around a turbine that are likely to experience certain levels of noise or shadow flicker.

With the Fall Zone Tool, a user can choose to view a setback based on the size of the turbine, as specified in the turbine specifications selected by the user, or to allow the tool to predict a fall zone radius using the formula proposed by Rogers et al. (2011), described in the Wind Energy Chapter of this document (See Ch. 4 Figure 5).

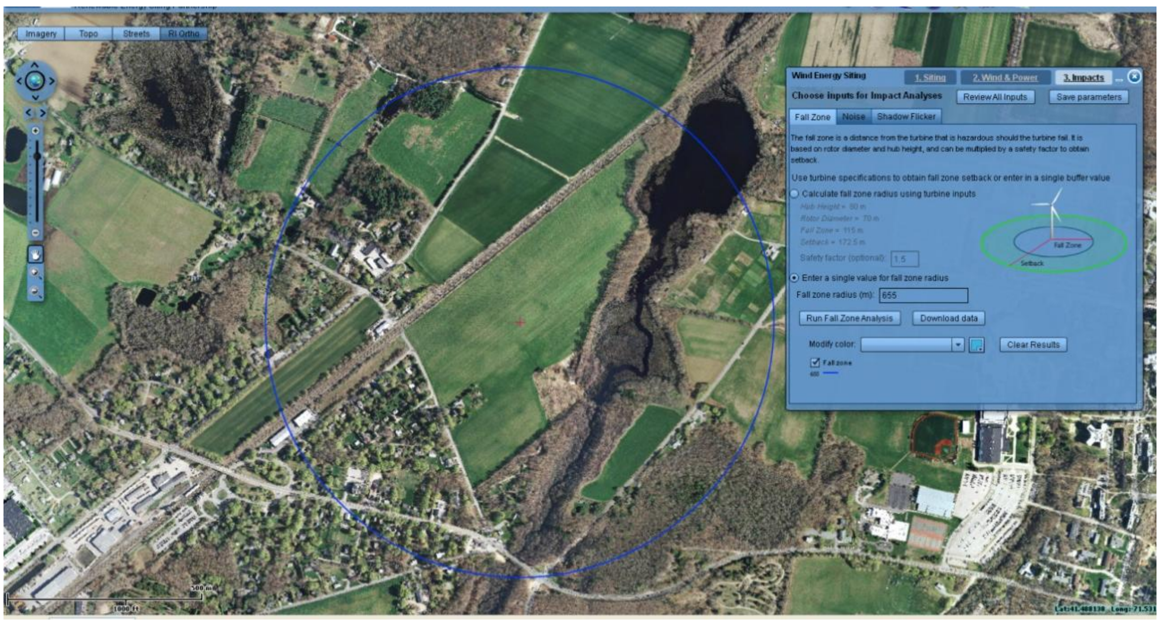
The Noise Modeling Tool allows users to input the source volume level of the turbine selected, as well as parameters of the locale, such as foliage height, humidity, housing density, temperature, and the receiver height (e.g. the height of a person hearing the noise emitted). Up to three noise thresholds can be mapped at once (see Ch. 4 Figure 6), allowing the user to visualize the impact of turbine noise at several different distances from the turbine.

Lastly, with Shadow Flicker Tool, users can model up to five shadow flicker zones, each representing a predicted maximum number of hours of shadow flicker per year (see Ch. 4 Figure 7 and Potty *et al.* 2012). Like the other two tools, this tool enables community members to visualize how they and their neighbors might be affected by a proposed turbine, and to explore the predicted impacts associated with an array of alternative siting options.

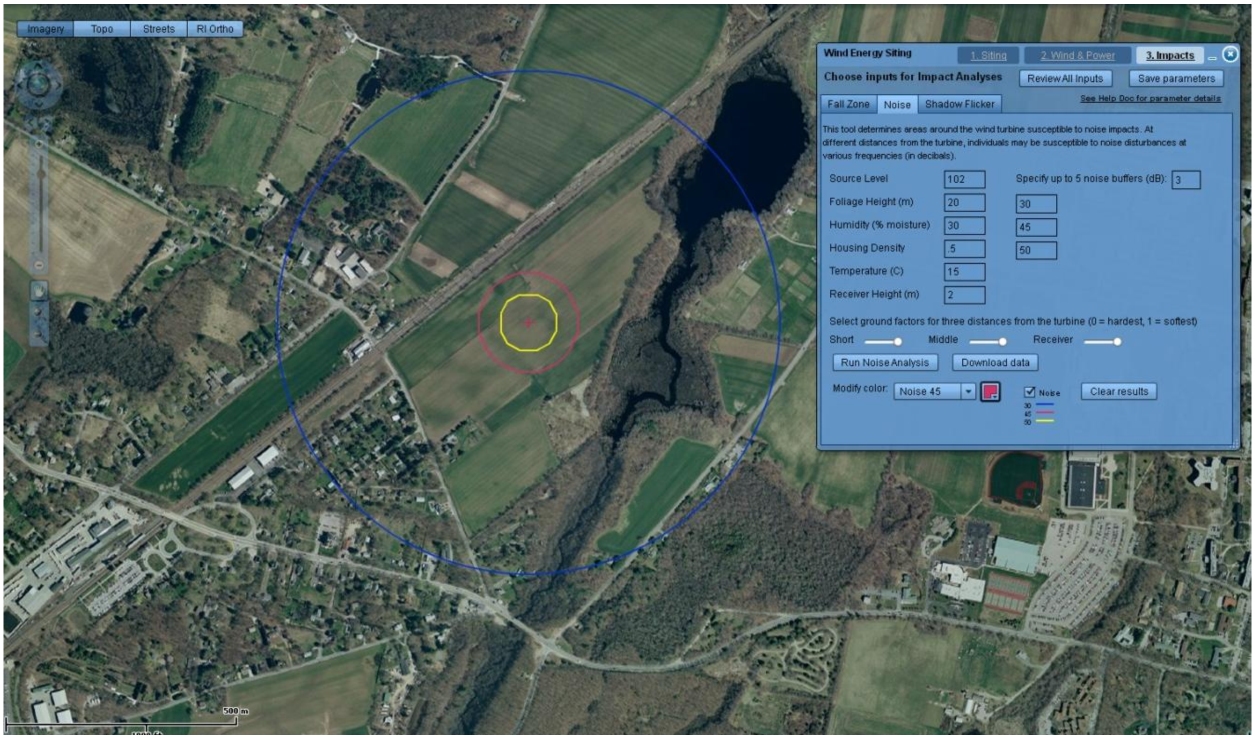
a)



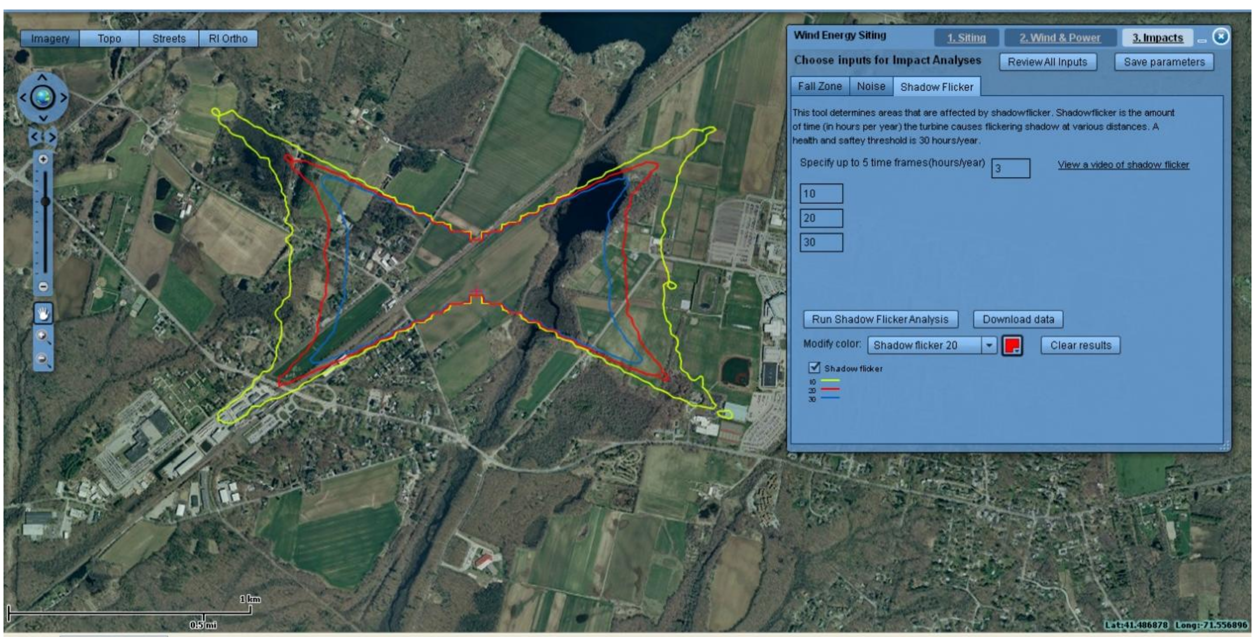
b)



Ch. 4 Figure 5. Fall Zone Setbacks (a) based on the height of the turbine specified (e.g. 1.5* Total Turbine Height); (b) Setback based on a certain radius (e.g. distance calculated by methodology described in the Wind Chapter conducted by Rogers et al. (2011)).



Ch. 4 Figure 6. Noise Impact Zones.



Ch. 4 Figure 7. Shadow Flicker Impact Zones.

4.3 Appendix A3: Hydropower

The Hydropower Viewer provides a geospatial platform for visualizing the potential opportunities and constraints associated with retrofitting existing dams in Rhode Island for hydroelectric generation. For more information on hydropower in Rhode Island and the RESP research and stakeholder process used to inform this viewer, please refer to the Hydropower Chapter in Volume I of this report or the Hydropower Resource Assessment Technical Report in Volume II of this report. The following layers were compiled for the hydropower viewer:

1. Fish Species
2. Dam Information
3. Hydrography
4. Water Quality
5. Cultural and Scenic
6. RI Imagery

Ch. 4 Table 2. Hydropower Viewer Layers.

Data Types	Data Item	Categorized by	Parameters	Timeframe	Lat/Long	Source
Fish Species	Fish Species	Presence/absence by watershed	Alewife, american shad, american eel, brook trout, long nosed dace, black nosed dace, white sucker, common shiner, fall fish, creek chub sucker and tessellated darter	N/A	No	RIDEM Division of Fish & Wildlife
Dam Information	Dam Drainage Areas	N/A	N/A	N/A	GIS	URI Environmental Data Center
Dam Information	Hydropower Potential	KW potential	N/A	N/A	Yes	RESP
Dam Information	Hydropower Projects	Licensed, Exempt, Pre-permitted	see Existing & Proposed Hydropower Projects spreadsheet	Date Issued	Yes	FERC, US Fish & Wildlife
Dam Information	Dam Hazard Level	High, Significant, Low, N/A	see RIDEM 2011 Dam Information Update spreadsheet	Date constructed	Yes	RIDEM Office of Water Resources
Dam Information	Dam Height	<5 ft, between 5 and 10 ft, between 10 and 20 ft, >20 ft	see RIDEM 2011 Dam Information Update spreadsheet	Date constructed	Yes	RIDEM Office of Water Resources
Dam Information	Dam Locations	N/A	see RIDEM 2011 Dam Information Update spreadsheet	Date constructed	Yes	RIDEM Office of Water Resources

Hydrography	USGS Stream Gages	N/A	Drainage area, flow statistics	N/A	Yes	USGS National Water Information System: Web Interface
Hydrography	Watersheds	HUC 8, HUC 10, and HUC 12 Watersheds	N/A	N/A	GIS	URI Environmental Data Center
Hydrography	Lakes/Ponds	N/A	N/A	N/A	GIS	URI Environmental Data Center
Hydrography	Rivers/Streams	N/A	N/A	N/A	GIS	URI Environmental Data Center
Hydrography	Cold Water Streams	N/A	N/A	N/A	GIS	RIDEM Division of Fish & Wildlife
Water Quality	Dissolved oxygen impaired water bodies	N/A	N/A	N/A	GIS	RIDEM Office of Water Resources, Alisa Richardson
Water Quality	Special Resource Protection Waters (SRPW)	N/A	Water Quality Standard, Water Quality Category	N/A	GIS	RIDEM Office of Water Resources, Water Quality Regulations, Appendix D
Water Quality	Integrated Water Quality and Monitoring Assessment Report waters (IMQMA)	Water Quality Category	Water Quality Standard, Water Quality Category	N/A	GIS	URI Environmental Data Center
Cultural & Scenic	Wild and Scenic Waterways	N/A	N/A	N/A	GIS	Wood-Pawcatuck Watershed Association
Cultural & Scenic	National Heritage Corridors	N/A	N/A	N/A	GIS	URI Environmental Data Center
Cultural & Scenic	National Register Dams	Eligible, Formerly Listed, Listed	N/A	N/A	Yes	RIHPHC, Rick Greenwood
RI Imagery	RI Imagery	N/A	N/A	N/A	GIS	URI Environmental Data Center

4.4 Appendix A4: Solar

The Solar Viewer provides a geospatial platform for visualizing the potential opportunities and constraints associated with deploying solar energy systems on closed or capped Rhode Island landfills. For more information on landfill solar in Rhode Island and the RESP research and stakeholder process used to inform this viewer, please refer to the Solar Chapter in Volume I of this report. The following layers were compiled for solar viewer:

1. Landfill Locations
2. Landfill View
3. Statewide View
4. Elevation
5. RI Imagery

Ch. 4 Table 3. Solar Viewer Layers.

Data Types	Data Item	Categorized by	Parameters	Timeframe	Lat/Long	Source	Notes
Landfill Locations	TMY3 Monitoring Locations	N/A	N/A	N/A	YES	National Renewable Energy Laboratory (NREL)	TMY3 meteorological stations listed in the National Solar Radiation Data Base (NSRDB)
Landfill Locations	Landfill Points	N/A	N/A	N/A	YES	URI Environmental Data Center	From CERCLIS Reports, RIDEM Office of Waste Management
Landfill Locations	Landfill Parcels	N/A	N/A	N/A	GIS	URI Environmental Data Center	
Landfill View	Aspect	South 15 degrees, South 30 degrees	N/A	N/A	N/A	URI Environmental Data Center	
Landfill View	Slope	3% and 6%	N/A	N/A	N/A	URI Environmental Data Center	
Landfill View	Annual Solar Potential	N/A	N/A	N/A	N/A	URI Environmental Data Center	Based on ArcGIS Solar Analyst
Statewide View	Aspect	South 15 degrees, South 30 degrees	N/A	N/A	N/A	URI Environmental Data Center	
Statewide View	Slope	3% and 6%	N/A	N/A	N/A	URI Environmental Data Center	
Statewide View	Annual Solar Potential	N/A	N/A	N/A	N/A	URI Environmental Data Center	Based on ArcGIS Solar Analyst
Elevation	Elevation	N/A	N/A	N/A	N/A	URI Environmental Data Center	
Elevation	Hillshade	N/A	N/A	N/A	N/A	URI Environmental Data Center	
RI Imagery	RI Imagery	N/A	N/A	N/A	GIS	URI Environmental Data Center	

4.5 Appendix A5: Consumption & Efficiency

The Consumption & Efficiency Viewer provides a geospatial platform for visualizing the potential opportunities to harvest energy savings in Rhode Island by reducing demand or increasing efficiency. The following layers were compiled for the consumption & efficiency viewer:

1. Green Development
2. Commercial Electric Use
3. Commercial Gas Use
4. Residential Electric Use
5. Residential Gas Use
6. Population
7. RI Imagery

Ch. 4 Table 4. Consumption & Efficiency Viewer Layers.

Data Types	Data Item	Categorized by	Parameters	Timeframe	Lat/Long	Source	Notes
Green Development	Cogeneration Facilities	Plant by Fuel Type	Name, Application, Capacity, Fuel Type	N/A	Address	See notes	http://www.eea-inc.com/chpdata/States/RI.html http://www.energy.ri.gov/documents/renewable/dg_report.pdf
Green Development	Deep Energy Retrofit Installers/Contractors	N/A	Company Name, Address, Telephone, Website	N/A	Address	National Grid	http://www.powerofaction.com/media/pdf/derlist.pdf
Green Development	Green Buildings	N/A	Name, LEED Status, LEED Certification, Address	N/A	Address	USGBC	http://marketplace.usgbcri.org/green-projects/
Green Development	Collaborative for High Performance Schools (CHPS)	N/A	Location	N/A	Address	CHPS website	
Consumption	Electricity Consumption	Sector	Customer Count by ZIP (# of customers), Usage by ZIP (kWh)	2009 to 2011	Yes (URI)	National Grid	Sector - Residential, Commercial, Industrial, Other
Consumption	Natural Gas Consumption	Sector	Customer Count by ZIP (# of customers), Usage by ZIP (MMBtu)	2009 to 2011	Yes (URI)	National Grid	Sector - Residential, Commercial, Industrial, Other
Consumption	Average Household Electricity Consumption	Sector	Usage per ZIP divided by customer count per ZIP	2009 to 2011	Yes (URI)	National Grid	Sector - Residential, Commercial, Industrial, Other
Consumption	Average Household Gas Consumption	Sector	Usage per ZIP divided by customer count per ZIP	2009 to 2011	Yes (URI)	National Grid	Sector - Residential, Commercial, Industrial, Other
Population	Residential Housing Type	Multifamily, Single Family, Seasonal	N/A	N/A	GIS	URI Environmental Data Center	E911 Database
Population	People Counts	5, 10, 20, 50, 100, 150, >150	N/A	N/A	GIS	URI Environmental Data Center	USGS Western Geographic Science Center methodology
Population	People per km2	40, 80, 160, 320, 640, 1280, >1280	N/A	N/A	GIS	URI Environmental Data Center	USGS Western Geographic Science Center methodology

5. Appendix B: Rhode Island Energy Data Center Technical Documentation

The table below catalogues the Rhode Island-specific datasets compiled for the RI Energy Data Center. Full technical documentation describing methodology and contents of the datasets can be found below.

Ch. 4 Table 5. Rhode Island Energy Data Center Electricity and Fuel Data.

#	Data Type	Data Item	Categorized by	Parameters	Timeframe	Lat/Long	Source	Notes
1	Electricity	Electric Generation	Plant by Fuel	Net electricity generation (MWH), Total fuel Consumption (Physical Unit), Calculated CO2 Emissions (Tons)	Monthly, Yearly	Yes	EIA	Physical Unit - Measuring unit for total fuel consumption presented as a column in the data sheet.
2		Electric Monitored Emissions	Plant	CO2, Sox and NOx Emissions (Tons)	Monthly, Yearly	Yes	Clean Air Market, EPA	
3		Electric Capacity	Plant , Generator	Name Plate Capacity (MW), Fuel Used (1, 2)	Yearly	Yes	EIA	
4		Whole Sale Market	RI Region	Peak Demand (MW), Average Day Ahead LMPs ($/Mwh), Average Real Time LMPs ($/MWH), Total Energy (Gwh)	Daily, Monthly, Yearly	No	ISO-NE	PkDEMD (MW) - Peak Demand, AvgDALMP ($/MWH) - Average Day Ahead Locational Marginal Price, AvgRTLMP ($/MWH) - Average Real Time Locational Marginal Price, Energy (GWH) - Total Energy For Settlement Process
5		Electricity Retail	Sector	Retail Sales (Mwh), Expenditure(Thousand $), Price (Cents/Kwh) Calculated CO2 Emissions (Tons)	Monthly, Yearly	No	EIA	Sector - Commercial, Industrial, Residential, Transportation
6		RGGI Summary		Auction-Prices, Revenue State Emissions	Quarterly	Yes (For Power Plants)	RGGI, Inc.	State Emissions - Are same as Clean Air Market except just for RGGI power plant facilities.
7	Fuels	Natural Gas	Sector	Price ($/Mcf & $/Mmbtu), Quantity (Mmcf & Mmbtu), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, City Gate (Whole sale)
8		Motor Gasoline	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail

9		Diesel Fuel	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
10		#2 Distillate Fuel	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
11		Jet Fuel	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
12		Residual Fuel	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly, Monthly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
13		Kerosene	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
14		Propane	Sector	Price (Cents/Gallon), Quantity (Thousand Gallon), Expenditure ($), Calculated CO2 Emissions (Tons)	Yearly	No	EIA	Sector - Commercial, Industrial, Residential, Electric Power Generation, Transportation, Whole sale and Retail
15	Efficiency	Electricity Efficiency	Sector	Cost-Program Administration ($), Customer ($), Total ($) Benefits-Electric ($), Non Electric ($), Total ($) Savings- Annual, Lifetime (MWh) & Peak (MW)	Yearly	No	Program Administrator Annual Reports	Sector - Residential, Commercial, Low Income and Total
16		Natural Gas Efficiency	Sector	Cost-Program Administration ($), Customer ($), Total ($) Benefits-Gas ($), Non Gas($), Total ($) Savings- Annual, Lifetime (MCF)	Yearly	No	Program Administrator Annual Reports	Sector - Residential, Commercial, Low Income and Total
17	Heating Fuel Mix		Fuel	Number of housing units by zipcode, Percentage of total housing units by zipcode	2000	Yes (URI)	Census 2000	

5.1 Electric Generation Dataset

The Electric Generation dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects plant-level data on monthly generation and fuel consumption using Form EIA-923 (previously Forms EIA-920 & EIA-906), “Power Plants Operational Report”, from utility and non-utility electric power plants and from combined heat and power (CHP) plants. A monthly sample of approximately 1600 plants is used including a census of nuclear and pumped storage hydroelectric plants. In addition, approximately 3,700 plants data representative of all other generators with a capacity 1 MW or greater is collected annually. Fuel storage terminals which receive stock destined for electricity generation are also included in the survey.[3]

The prepared dataset contains each plant’s total fuel consumption and electric generation monthly and yearly values by fuel types. Monthly values are directly based on EIA data. Yearly values are derived using the sum of the monthly values. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology
Electric Generation Monthly (Data points represent values by each fuel type consumed by facilities by month)	Region	State postal abbreviation where the facility or plant is located (All New England States – CT, VT, RI, MA, ME, NH).	Form EIA 906, EIA 920 and EIA 923[4].
	Facility ID	EIA plant identification number.	
	Facility Name	Name of the facility or plant. Note that State-Fuel level increments values are adjustment made by EIA to correct survey errors or to estimate values for out of sample plants. These values should be included when calculating state totals.	
	Year	Electric generation year. Note that included data for the year 2011 is not final and can change as EIA is still working on related statistical procedures and will be posting the finalized version around December, 2012.	
	Month	Electric generation month.	
	Fuel Code	The fuel code reported to EIA. See the code’s full names in the Table 1 below.	
	Total Fuel Consumed (Physical Unit)	Consumption of the fuel represented by fuel code in physical units in the facility. Please see physical units by fuel code in the Table 1 below. These units are as per EIA with some corrections.	
	Total Fuel Consumed (MMBTU)	Consumption of the fuel represented by fuel code in millions of BTUs in the facility.	
	Electricity Net Generation (MWh)	Net generation of electricity in the facility.	
	Locational Coordinates (Latitude, Longitude)	Latitude and Longitude values of the facility.	EIA-860, 2010 data requested from EIA. Some points were

[3] http://www.eia.gov/electricity/monthly/pdf/appenc.pdf
[4] http://www.eia.gov/cneaf/electricity/page/eia906_920.html

			modified to update position information.
	Emission Factors (Metric Tons CO_2/MMBTU)	Carbon dioxide emission factor for the fuel represented by fuel code. See the emission factor values by fuel type in the Table 1 below.	Derived from EIA values.[5]
	Calculated Emissions (Metric Tons CO_2)	Carbon dioxide emissions due to total fuel consumption in the power plants.	Product of emission factors (Metric Tons CO_2/Physical Unit) and total consumption (Physical Unit).
Electric Generation Yearly (Data points represent values by each fuel type consumed by facilities by year)	Region	Same as Electric Generation Monthly.	Derived from Electric Generation Monthly.
	Facility ID		
	Facility Name		
	Year		
	Fuel Code		
	Total Fuel Consumed (Physical Unit)	Yearly total of Electric Generation Monthly values.	
	Total Fuel Consumed (MMBTU)		
	Electricity Net Generation (MWh)		
	Locational Coordinates (Latitude, Longitude)	Same as Electric Generation Monthly.	
	Emission Factors (Metric Tons CO_2/Physical Unit)		
	Calculated Emissions (Metric Tons CO_2)		

Fuel Type Code	**Fuel Name**	**Physical Unit**	**Emission Factor (Tons CO_2/MMBTU)**
BIT	Coal (Anthracite and Bituminous Coal)	short tons	0.093
DFO	Petroleum Distillate (Distillate Fuel Oil)	barrels	0.073
JF	Petroleum Distillate (Jet Fuel)	barrels	0.071
KER	Petroleum Distillate (Kerosene)	barrels	0.072
NG	Natural Gas	mcf (thousand cubic feet)	0.053
PG	Propane gas	mcf (thousand cubic feet)	0.063
RFO	Residual Fuel Oil	barrels	0.079
SC	Coal (Synthetic Coal)	short tons	0.093
SUB	Coal (Sub-bituminous Coal)	short tons	0.097
WO	Waste Oil	barrels	0.095
BFG	Blast Furnace Gas	mcf (thousand cubic feet)	
BLQ	Other Renewables (Black Liquor)	short tons	
HPS	Other Renewables(Pumped Storage Hydroelectric)		

[5] http://www.eia.gov/oiaf/1605/coefficients.html

LFG	Other Renewables (Landfill Gas)	mcf (thousand cubic feet)	
MSB	Other Renewables (Municipal Solid Waste – Biogenic component)	short tons	
MSN	Other (Municipal Solid Waste – Non-biogenic components)	short tons	
MSW	Municipal Solid Waste	short tons	0.042
MWH	Other		
NUC	Nuclear		
OBG	Other Renewables (Other Biomass Gas)	mcf (thousand cubic feet)	
OBL	Other Renewables (Other Biomass Liquids)	barrels	
OBS	Other Renewables (Other Biomass Solids)	short tons	
OG	Other Gas	mcf (thousand cubic feet)	
OOG	Other Gas	mcf (thousand cubic feet)	
OTH	Other		
PUR	Other (Purchased Steam)	mcf (thousand cubic feet)	
SLW	Other Renewables (Sludge Waste)	short tons	
SUN	Solar		
TDF	Other (Tire-derived Fuels)	short tons	
WAT	Hydroelectric		
WDL	Other Renewables (Wood Waste Liquids excluding Black Liquor)	barrels	
WDS	Other Renewables (Wood/Wood Waste Solids)	short tons	
WND	Other Renewables (Wind)		

5.2 Electric Capacity Dataset

The Electric Capacity dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects data related to power plants, 5-year plans for constructing new plants and added, modified and retired generating units in existing plants using Form EIA-860, "Annual Electric Generator Report". All existing and planned electric plants in the country with a total generator nameplate capacity of 1 or more megawatts are included in this survey.[6] Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology
Capacity Data (Data points represent plant capacity values by its generator units)	Year	Year for which electric capacity is reported.	EIA – 860[7] .
	Facility ID	EIA-assigned plant code. Same as Facility ID in the electric generation dataset.	
	Facility Name	Name of the facility or plant name. Equivalent to Facility Name in the electric generation dataset.	
	Region	Plant state postal abbreviation (All New England States – CT, VT, RI, MA, ME, NH).	
	UNIT_ID	Generating unit identification number.	
	Unit Status	The status of the generator. Generators can be proposed, operating, on standby or can be retired. Please see details of the status code in the Table 1 below.	
	Nameplate Capacity (MW)	The highest value on the generator nameplate capacity in megawatts rounded to the nearest tenth.	
	Summer Capacity (MW)	The net summer capacity.	
	Winter Capacity (MW)	The net winter capacity.	
	Start Year	Year the generator began commercial operation. For proposed generator value is the most recently updated effective year on which it is scheduled to start operation.	
	Fuel_Code_1	The code representing the most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Fuel_Code_2	The code representing the second most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Fuel_Code_3	The code representing the third most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Fuel_Code_4	The code representing the fourth most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Fuel_Code_5	The code representing the fifth most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Fuel_Code_6	The code representing the sixth most predominant type of energy that fuels the generating unit. Please see details of the fuel codes in the Table 2 below.	
	Locational Coordinates (Latitude, Longitude)	Latitude and Longitude values of the facility.	EIA-860, 2010 data requested from EIA. Some points were modified to update position information.

[6] http://www.eia.gov/electricity/monthly/pdf/appenc.pdf
[7] http://www.eia.gov/cneaf/electricity/page/eia860.html

Status	Status Code	Description[8]
Existing	OP	Operating - in service (commercial operation) and producing some electricity. Includes peaking units that are run on an as needed (intermittent or seasonal) basis.
	SB, BU	Standby/Backup - available for service but not normally used (has little or no generation during the year) for this reporting period.
	OA	Out of service - was not used for some or all of the reporting period but was either returned to service on December 31 or will be returned to service in the next calendar year.
	OS	Out of service – was not used for some or all of the reporting period and is NOT expected to be returned to service in the next calendar year.
Proposed	TS	Construction complete, but not yet in commercial operation (including low power testing of nuclear units).
	P	Planned for installation but regulatory approvals not initiated; Not under construction.
	L	Regulatory approvals pending. Not under construction but site preparation could be underway.
	T	Regulatory approvals received. Not under construction but site preparation could be underway.
	U	Under construction, less than or equal to 50 percent complete (based on construction time to date of operation).
	V	Under construction, more than 50 percent complete (based on construction time to date of operation).
Other	RE	Retired - no longer in service and not expected to be returned to service.
	IP	Planned new generator canceled, indefinitely postponed, or no longer in resource plan.
	OT	Other.

Fuel Type Code	Fuel Name
BIT	Coal (Anthracite and Bituminous Coal)
DFO	Petroleum Distillate (Distillate Fuel Oil)
JF	Petroleum Distillate (Jet Fuel)
KER	Petroleum Distillate (Kerosene)
NG	Natural Gas
PG	Propane gas
RFO	Residual Fuel Oil
SC	Coal (Synthetic Coal)
SUB	Coal (Sub-bituminous Coal)
WO	Waste Oil
BFG	Blast Furnace Gas
BLQ	Other Renewables (Black Liquor)
HPS	Other Renewables(Pumped Storage Hydroelectric)
LFG	Other Renewables (Landfill Gas)
MSB	Other Renewables (Municipal Solid Waste – Biogenic component)

[8] http://www.eia.gov/cneaf/electricity/page/eia860.html

MSN	Other (Municipal Solid Waste – Non-biogenic components)
MSW	Municipal Solid Waste
MWH	Other
NUC	Nuclear
OBG	Other Renewables (Other Biomass Gas)
OBL	Other Renewables (Other Biomass Liquids)
OBS	Other Renewables (Other Biomass Solids)
OG	Other Gas
OOG	Other Gas
OTH	Other
PUR	Other (Purchased Steam)
SLW	Other Renewables (Sludge Waste)
SUN	Solar
TDF	Other (Tire-derived Fuels)
WAT	Hydroelectric
WDL	Other Renewables (Wood Waste Liquids excluding Black Liquor)
WDS	Other Renewables (Wood/Wood Waste Solids)
WND	Other Renewables (Wind)

5.3 Electric Monitored Emissions Dataset

Electric Monitored Emissions dataset is prepared using Daily Monitored Emissions data[9] from the United States Environmental Protection Agency (EPA). The agency collects this data under the Clean Air Markets (CAM) program[10]. CAM includes various market-based regulatory approaches such as Acid Rain program under which each regulated source unit is required to continuously measure and record its SO_2, NO_x and CO_2 emissions. Regulated units are those with above 25 megawatt (MW) capacity. New units under 25 MW capacity that use fuel with sulfur content higher than 0.05 percent by weight are also regulated by the program. Units are allowed to measure CO_2 emissions using mass balance estimation; or continuous emissions monitoring with a CO_2 or oxygen monitor and a flow monitor to compute emissions in tons per hour[11]. The prepared dataset is divided into Daily Emissions, Monthly Emissions and Yearly Emissions subsets. Daily Emissions data is directly based on EPA data. Monthly and Yearly Emissions datasets are derived from Daily Emissions data. Dataset specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology
Daily Emissions	FACILITY_NAME	Name of Facility. Equivalent to Facility Name in the electric generation dataset.	Clean Air Markets, EPA[12].
	ORISPL_CODE	EPA Facility ID. Same as EIA Facility ID.	
	UNIT ID	EPA Generating unit ID. Equivalent to EIA Unit ID in the capacity dataset.	
	STATE	State postal abbreviation (All New England States – CT, VT, RI, MA, ME, NH).	
	Date	Date of the data.	
	Year	Year of the data.	
	Month	Month of the data.	
	Day	Day of the data.	
	SO_2_MASS (Short Tons)	Sulfur dioxide emissions from the facilities.	
	NO_X_MASS (Short Tons)	Nitrogen oxides emissions from the facilities.	
	CO_2_MASS (Short Tons)	Carbon di oxide emissions from the facilities.	
	Locational Coordinates (Latitude, Longitude)	Latitude and Longitude values of the facility.	EIA-860, 2010 data requested from EIA. Some points were modified to update position information.
Monthly Emissions	FACILITY_NAME	Same as Daily Emissions data.	Derived from Daily Emissions.
	ORISPL_CODE		
	STATE		
	Year		
	Month		
	SO_2_MASS (Short Tons)	Monthly total of Daily Emissions data.	
	NO_X_MASS (Short Tons)		
	CO_2_MASS (Short Tons)		
	Locational Coordinates (Latitude,	Same as Daily Emissions data.	

9 http://ampd.epa.gov/ampd
10 http://www.epa.gov/airmarkets/index.html
11 http://www.epa.gov/airmarkets/emissions/continuous-factsheet.html
12 ftp://ftp.epa.gov/dmdnload/emissions/daily/quarterly

	Longitude)		
Yearly Emissions	FACILITY_NAME	Same as Daily Emissions data.	
	ORISPL_CODE		
	STATE		
	Year		
	SO2_MASS (Short Tons)	Yearly total of Daily Emissions data.	
	NOX_MASS (Short Tons)		
	CO2_MASS (Short Tons)		
	Locational Coordinates (Latitude, Longitude)	Same as Daily Emissions.	

5.4 Electric Wholesales Dataset

Electric Wholesales dataset is prepared using ISO-New England (ISO-NE) daily and monthly summary of hourly data. ISO-NE is the operator of the New England wholesale electric power markets. Generators sell their electricity through the wholesale market to utilities, marketers and others entities, which further sell it to residential, commercial, industrial and other end users.[13]

The prepared dataset is divided into Daily, Monthly and Yearly subsets. Daily and Monthly data is directly based on ISO-NE data. Yearly data is derived from Monthly data. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology
Daily	Load Zones	Postal abbreviation of region or control area names divided by ISO-New England as different load zones. ISO-New England Control Area (ISO-NE CA) level (all region combined) values are also included. Full names of the control areas are given in the Table 1 below.	ISO-NE Daily Data[14].
	Year	Year of the data.	
	Month	Month of the data.	
	Day	Day of the data.	
	PkDEMD (MW)	The ISO-New England load zones actual daily Non-PTF peak demand. Non-PTF Demand is the load used in the settlement process and is calculated as: Non-PTF Demand = [non-dispatchable + unmetered + station service].	
	AvgDALMP ($/MWH)	The average hourly day ahead Locational Marginal Price (LMP) for a load zone in a given day. The locational marginal price at a specific location is the cost of generating the next MW to supply load at a specific location.	
	AvgRTLMP ($/MWH)	The average hourly real time Locational Marginal Price (LMP) for a load zone in a given day.	
	Energy (GWH)	The daily non-PTF energy demand for ISO New England Control Area (ISO-NE CA) and the 8 load zones.	
Monthly	Load Zones	Same as Daily Data.	ISO-NE Monthly Data[15].
	Year		
	Month		
	PkDEMD (MW)	The ISO-New England load zones actual monthly Non-PTF peak demand.	
	AvgDALMP ($/MWH)	The average hourly day ahead Locational Marginal Price (LMP) for a load zone in the month.	
	AvgRTLMP ($/MWH)	The average hourly real time Locational Marginal Price (LMP) for a load zone in the month.	
	Energy (GWH)	The monthly non-PTF energy demand for ISO New England Control Area (ISO-NE CA) and the 8 load zones.	

13 http://www.iso-ne.com/markets/index.html
14 http://www.iso-ne.com/markets/hstdata/znl_info/daily/
15 http://www.iso-ne.com/markets/hstdata/znl_info/monthly/

Yearly	Load Zones	Same as Daily Data.	Derived using ISO-NE Monthly data.
	Year		
	PkDEMD (MW)	Yearly maximum of monthly data.	
	AvgDALMP ($/MWH)	Yearly average of Monthly data.	
	AvgRTLMP ($/MWH)		
	Energy (GWH)	Yearly total of Monthly data.	

Load Zones	**Full Name**
ISO-NE CA	ISO New England Control Area
CT	Connecticut
RI	Rhode Island
ME	Maine
NH	New Hampshire
VT	Vermont
SEMA	Southeast Massachusetts
WCMA	West-Central Massachussetts
NEMABOS	Northeast Massachussetts/Boston

5.5 Electric Retail Sales Dataset

The Electric Retail Sales dataset is prepared using data from United States Energy Information Administration (EIA). The agency collects samples of monthly data of the 450 largest electric utilities and a census of energy service providers in deregulated markets using Form EIA-826, "Monthly Electric Utility Sales and Revenues with State Distribution Report".[16]

The prepared dataset is divided into monthly and yearly data. Monthly data is based on EIA data. Yearly data is derived using Monthly data. Dataset specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology
Monthly Data	Region	State postal abbreviation for which the utility reported values (All New England States – CT, VT, RI, MA, ME, NH).	EIA 826.[17]
	Utility_Name	Utility Name. Note that "Total EPM" value represents state totals. State Level Adjustment values are adjustments made by EIA to correct survey errors or to estimate values for out of sample utilities or service providers. These values should be included when calculating state totals.	
	Utility_ID	EIA Unique utility identification number.	
	Year	Reported year of the data.	
	Month	Reported month of the data.	
	Sector	Sector name. Full name of the sector codes are given in the Table 1 below.	
	Revenue (Thousand $)	Revenue from sales to customers.	
	Sales (Mwh)	Sales to customers.	
	Calculated Price (Cents/Kwh)	Derived average price using revenue and sales values.	Revenue divided by sales.
	Emission Factor (Metric Tons/MWh)	New England electricity generation CO_2 average emission rate. See the Table 2 below for details.	ISO-New England (ISO-NE) 2010 Emission Report.[18]
	Calculated CO_2 Emissions (Metric Tons)	CO_2 emission equivalent caused by electricity sales or consumption.	Sales times Emission Factor.
	Number of customers	Number of customers.	EIA 826.
Yearly Data	Region	Same as Monthly Data.	Derived using Monthly Data.
	Utility_Name		
	Utility_ID		
	Year		

[16] http://www.eia.gov/electricity/monthly/pdf/appenc.pdf
[17] http://www.eia.gov/cneaf/electricity/page/eia826.html
[18] http://www.iso-ne.com/genrtion_resrcs/reports/emission/final_2010_emissions_report_v2.pdf

	Sector		
	Revenue (Thousand $)	Yearly total of Monthly Data values.	
	Sales (Mwh)		
	Calculated Price (Cents/Kwh)	Derived average price using revenue and sales values.	Same as Monthly Data.
	Calculated CO_2 Emissions (Metric Tons)	CO_2 emission equivalent caused by electricity sales or consumption.	
	Number of customers	Yearly total of Monthly Data values.	Derived using Monthly Data.

Sector	**Name**
AC	Transportation/Other
CC	Commercial
IC	Industrial
RC	Residential
TC	Total Energy

Year	**Annual Average CO_2 Emission Rate (lb/MWh)**	**Annual Average CO_2 Emission Rate (Metric Tons/MWh)**	**Region**	**Source/Assumption**
1999	1009	0.4579851	New England Avg.	ISO-NE (Emission Report 2010)
2000	913	0.4144107	New England Avg.	ISO-NE (Emission Report 2010)
2001	930	0.422127	New England Avg.	ISO-NE (Emission Report 2010)
2002	909	0.4125951	New England Avg.	ISO-NE (Emission Report 2010)
2003	970	0.440283	New England Avg.	ISO-NE (Emission Report 2010)
2004	876	0.3976164	New England Avg.	ISO-NE (Emission Report 2010)
2005	919	0.4171341	New England Avg.	ISO-NE (Emission Report 2010)
2006	808	0.3667512	New England Avg.	ISO-NE (Emission Report 2010)
2007	905	0.4107795	New England Avg.	ISO-NE (Emission Report 2010)
2008	890	0.403971	New England Avg.	ISO-NE (Emission Report 2010)
2009	828	0.3758292	New England Avg.	ISO-NE (Emission Report 2010)
2010	829	0.3762831	New England Avg.	ISO-NE (Emission Report 2010)
2011	829	0.3762831	New England Avg.	Assumed
2012	829	0.3762831	New England Avg.	Assumed

5.6 Natural Gas Fuel Dataset

Natural gas dataset is prepared using United States Energy Information Administration (EIA) data. The agency collected city gate, residential, commercial and industrial prices data using Form EIA- 857, "Monthly Report of Natural Gas Purchase and Deliveries to Customers" and Form 910, "Monthly Natural Gas Marketer Survey". City gate prices represent the total cost paid by gas distribution companies for gas received from transmission (pipeline) companies at the delivery stations. Gas is further distributed to end use customers by local utilities. Industrial, residential and commercial prices are total values paid by customers inclusive of all taxes in procuring gas at their end use location. Electric Power price data is collected using Form EIA-923, "Power Plant Operations Report" from 2007-current and previously was collected by Federal Energy Regulatory Commission (FERC) Form – 423, "Cost and Quality of Fuels for Electric Plants Report" and EIA – 423, "Monthly Cost and Quality of Fuels for Electric Plants Report". All other price data is collected using Form EIA-176, "Annual Report of Natural and Supplemental Gas Supply and Disposition".[19]

EIA Collects natural gas quantity data using Form EIA-895, "Monthly and Annual Quantity and Value of Natural Gas Production Report" (2006 - annual only), Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers"; Form EIA-910, "Monthly Natural Gas Marketer Survey." , Form EIA-906, "Power Plant Report" , Form EIA-176, "Annual Report of Natural and Supplemental Gas Supply and Disposition" , Form EIA-886, "Annual Survey of Alternative Fueled Vehicle Suppliers and Users" , Form EIA-914, "Monthly Natural Gas Production Report" (2007 - current), Form EIA-923, "Power Plant Operations Report" (2007 - annual only, 2008 - monthly and annual electric), and EIA estimates. Volumes shown are on a pressure base of 14.73 psia at 60 degrees Fahrenheit.[20]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source/Methodology/Assumption
Monthly Retail Data	Fuel	Fuel code NG – Natural Gas.	EIA[21], EIA.[22]
	Region	State postal abbreviation for which price, quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH).	
	Year	Year of price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	

[19] http://www.eia.gov/dnav/ng/TblDefs/ng_pri_sum_tbldef2.asp
[20] http://www.eia.gov/dnav/ng/TblDefs/ng_cons_sum_tbldef2.asp
[21] http://www.eia.gov/naturalgas/data.cfm#prices
[22] http://www.eia.gov/naturalgas/data.cfm#consumption

	Sector	Sector name of the price, quantity, expenditure and emission values. Full name of the sector codes is given in the Table 1 below.	
	Price ($/MCF)	Monthly Retail Price.	
	Quantity (Mmcf)	Monthly Quantity.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/Mmcf)	Carbon dioxide emission factor value of 53.154 (Metric Tons CO_2/Mmcf) for natural gas.	Derived from EIA values.[23]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by natural gas consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	City Gate Price ($/MCF)	Monthly Wholesale Price.	
	Quantity (Mmcf)	Monthly Quantity.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity. Wholesale Price is assumed to be the same (does not substantially vary) for all sectors mentioned in the Table 1 except electric power sector to calculate Wholesale Expenditure.
	Emission Factor (Metric Tons CO_2/Mmcf)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly retail data.	Same as Monthly retail data.
	Region		
	Year		
	Sector		
	Price ($/MCF)	Yearly Retail Price.	
	Quantity (Mmcf)	Yearly Quantity.	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/Mmcf)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly retail data.	Same as Monthly retail data.
	Region		
	Sector		
	Year		
	City Gate Price ($/MCF)	Yearly Wholesale Price.	
	Quantity (Mmcf)	Yearly Quantity.	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity. Wholesale Price is assumed to be the same (does not substantially vary) for all sectors mentioned in the Table 1 except electric power sector to calculate Wholesale Expenditure.
	Emission Factor (Metric Tons CO_2/Mmcf)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

[23] http://www.eia.gov/oiaf/1605/coefficients.html

Sector	Full Name
CG	City Gate Price or Wholesale Price
TC	Total Energy
RC	Residential
CC	Commercial
IC	Industrial
IE	Electric Power
AC	Transportation

5.7 # 2 Distillate Fuel Dataset

#2 Distillate fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report" and EIA-782B, "Resellers'/Retailers' Monthly Petroleum Product Sales Report".[24] Prices are excluding taxes. The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[25]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source Details/Methodology
Monthly Retail Data	Fuel	Fuel code D2 - #2 Distillate Fuel.	EIA[26], EIA.[27]
	Region	State postal abbreviation for which price, quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy (TC).	
	Price ($/gal)	Monthly Retail Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 22.146 (lb CO_2/gal) or 0.010045 (Metric Tons CO_2/gal) for the fuel.	Derived from EPA values.[28]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		

[24] http://www.eia.gov/dnav/pet/TblDefs/pet_pri_dist_tbldef2.asp
[25] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
[26] http://www.eia.gov/dnav/pet/pet_pri_dist_a_EPD2_PTA_dpgal_m.htm
[27] http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[28] http://www.epa.gov/cpd/pdf/brochure.pdf

	Wholesale Price ($/gal)	Monthly Wholesale Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal) Calculated Emissions (Metric Tons CO_2)	Same as Monthly Retail data.	Same as Monthly Retail data.
Yearly Retail Data	Fuel Region Year Sector	Same as Monthly Retail data.	Same as Monthly Retail data.
	Price ($/gal)	Yearly Retail Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal) Calculated Emissions (Metric Tons CO_2)	Same as Monthly Retail data.	Same as Monthly Retail data.
Yearly Wholesale Data	Fuel Region Year Sector	Same as Monthly Retail data.	Same as Monthly Retail data.
	Wholesale Price ($/gal)	Yearly Wholesale Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal) Calculated Emissions (Metric Tons CO_2)	Same as Monthly Retail data.	Same as Monthly Retail data.

5.8 Diesel Fuel Dataset

Diesel fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report" and EIA-782B, "Resellers'/Retailers' Monthly Petroleum Product Sales Report". Prices are excluding taxes. In January 2007, ultra-low-sulfur diesel was added.[29] The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[30]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	**Parameters**	**Description**	**Source Details/Methodology**
Monthly Retail Data	Fuel	Fuel code DF, HS, LS, US – Diesel Fuel, High Sulfur, Low Sulfur and Ultra Low Sulfur Diesel Fuel. Data till the year 2006 is available as total Diesel Fuel and then from 2007 it gets distributed into High Sulfur, Low Sulfur and Ultra Low Sulfur Diesel Fuel. Fuel codes and their full names used are given in the Table 1 below.	EIA[31], EIA.[32]
	Region	State postal abbreviation for which price, quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy.	
	Price ($/gal)	Monthly Retail Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.010083 (Metric Tons CO_2/gal) for the fuel.	Derived from EPA values.[33]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		

[29] http://www.eia.gov/dnav/pet/TblDefs/pet_pri_dist_tbldef2.asp
[30] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
[31] http://www.eia.gov/dnav/pet/pet_pri_dist_a_EPD2_PTA_dpgal_m.htm
[32] http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[33] http://www.epa.gov/cpd/pdf/brochure.pdf

	Month		
	Sector		
	Wholesale Price ($/gal)	Monthly Wholesale Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	Price ($/gal)	Yearly Retail Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	Wholesale Price ($/gal)	Yearly Wholesale Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

Fuel Type	**Full Name**
DF	Diesel Fuel
HS	High Sulfur Diesel
LS	Low Sulfur Diesel
US	Ultra Low Sulfur Diesel

5.9 Residual Fuel Dataset

Residual fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report" and EIA-782B, "Resellers'/Retailers' Monthly Petroleum Product Sales Report".[34] Prices are excluding taxes. The fuel total consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[35] Annual consumption data by end use is collected from, Form EIA-821, "Annual Fuel Oil and Kerosene Sales Report".[36]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	**Parameters**	**Description**	**Source Details/Methodology/Assumption**
Monthly Retail Data	Fuel	Fuel code RF – Residual Fuel.	EIA[37], EIA.[38]
	Region	State postal abbreviation for which price, quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy.	
	Price ($/gal)	Monthly Retail Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.011823 (Metric Tons CO_2/gal).	Derived from EIA values.[39]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	Wholesale Price ($/gal)	Monthly Wholesale Price.	

[34] http://www.eia.gov/dnav/pet/TblDefs/pet_pri_resid_tbldef2.asp
[35] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
[36] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_821rsd_tbldef2.asp
[37] http://www.eia.gov/dnav/pet/pet_pri_resid_dcu_nus_m.htm
[38] http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[39] http://www.eia.gov/oiaf/1605/coefficients.html

	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector	Sector name of the price, quantity, expenditure and emission values. Full names of the sector codes given in the Table 1 below.	
	Price ($/gal)	Yearly Retail Price.	
	Quantity (Thousand gal)	Yearly Quantity.	EIA[40]
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity. Retail price is assumed to be the same (does not vary substantially) for all sectors mentioned in the Table 1 to calculate retail expenditure.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector	Sector name of the price, quantity, expenditure and emission values. Full names of the sector codes given in the Table 1 below.	
	Wholesale Price ($/gal)	Yearly Wholesale Price.	
	Quantity (Thousand gal)	Yearly Quantity.	Same as Yearly Retail data.
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity. Wholesale price is assumed to be the same (does not vary substantially) for all sectors mentioned in the Table 1 to calculate wholesale expenditure.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

[40] http://www.eia.gov/dnav/pet/pet_cons_821rsd_dcu_nus_a.htm

Sector	Description	Notes
TC	All Sector	Sum of other sectors will not add up to total sector values for annual data. This is because TC data is collected from a different EIA database as described earlier.
CC	Commercial	
IC	Industrial	
IE	Electric Power	
VB	Vessel Bunkering	
AC	Total Transportation	This data is available through EIA *File Transfer Protocol* (*FTP*) link.[41]

[41] http://tonto.eia.doe.gov/dnav/pet/xls/PET_CONS_821USEA_A_EPPR_VAT_MGAL_A.xls

5.10 Propane Fuel Dataset

Propane fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report" and EIA-782B, "Resellers'/Retailers' Monthly Petroleum Product Sales Report".[42] The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[43]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source Details/Methodology
Monthly Retail Data	Fuel	Fuel code LG – Propane Fuel.	EIA[44], EIA.[45]
	Region	State postal abbreviation for which quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH). Price values are given for the region of New England (PADD 1A).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy.	
	PADD1A Retail Price ($/gal)	Monthly Retail Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.005761 (Metric Tons CO_2/gal) for the fuel.	Derived from EIA values.[46]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	PADD1A Wholesale Price	Monthly Wholesale Price for the PADD1A	

42 http://www.eia.gov/dnav/pet/TblDefs/pet_pri_prop_tbldef2.asp
43 http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
44 http://www.eia.gov/dnav/pet/pet_pri_prop_a_EPLLPA_PTA_dpgal_m.htm
45 http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
46 http://www.eia.gov/oiaf/1605/coefficients.html

	($/gal)	(New England) region.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1A Retail Price ($/gal	Yearly Retail Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1A Wholesale Price ($/gal)	Yearly Wholesale Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

5.11 Kerosene Fuel Dataset

Kerosene fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report"[47] The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[48]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source Details/Methodology
Monthly Retail Data	Fuel	Fuel code KS – Kerosene Fuel.	EIA[49], EIA.[50]
	Region	State postal abbreviation for which quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH). Price values are given for the region of East Coast (PADD 1).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy.	
	PADD1 Retail Price ($/gal)	Monthly Retail Price for the PADD1 (East Coast) region.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.00976 (Metric Tons CO_2/gal) for the fuel.	Derived from EIA values.[51]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	PADD1 Wholesale Price ($/gal)	Monthly Wholesale Price for the PADD1 (East Coast) region.	
	Quantity (Thousand gal)	Monthly Quantity.	

[47] http://www.eia.gov/dnav/pet/TblDefs/pet_pri_refoth_tbldef2.asp
[48] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
[49] http://www.eia.gov/dnav/pet/pet_pri_refoth_dcu_nus_m.htm
[50] http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[51] http://www.eia.gov/oiaf/1605/coefficients.html

		EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1A Retail Price ($/gal	Yearly Retail Price for the PADD1 (East Coast) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1 Wholesale Price ($/gal)	Yearly Wholesale Price for the PADD1 (East Coast) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

5.12 Kerosene Type Jet Fuel Dataset

Kerosene Type Jet Fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report".[52] The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[53]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	**Parameters**	**Description**	**Source Details/Methodology**
Monthly Retail Data	Fuel	Fuel code JK – Kerosene Type Jet Fuel.	EIA[54], EIA.[55]
	Region	State postal abbreviation for which quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH). Price values are given for the region of New England (PADD 1A).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy.	
	PADD1A Retail Price ($/gal)	Monthly Retail Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.00957 (Metric Tons CO_2/gal) for the fuel.	Derived from EIA values.[56]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	PADD1A Wholesale Price ($/gal)	Monthly Wholesale Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Monthly Quantity.	

52 http://www.eia.gov/dnav/pet/TblDefs/pet_pri_refoth_tbldef2.asp
53 http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
54 http://www.eia.gov/dnav/pet/pet_pri_refoth_dcu_nus_m.htm
55 http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
56 http://www.eia.gov/oiaf/1605/coefficients.html

		EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1A Retail Price ($/gal	Yearly Retail Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	PADD1A Wholesale Price ($/gal)	Yearly Wholesale Price for the PADD1A (New England) region.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		

5.13 Motor Gasoline Fuel Dataset

Motor Gasoline Fuel dataset is prepared using United States Energy Information Administration (EIA) data. The agency collects fuel prices data using Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report" and EIA-782B, "Resellers'/Retailers' Monthly Petroleum Product Sales Report".[57] The consumption data is collected using Forms EIA-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption".[58]

The prepared dataset is divided into Monthly Retail, Monthly Wholesale, Yearly Retail and Yearly Wholesale data subsets based on inputs from EIA. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source Details/Methodology
Monthly Retail Data	Fuel	Fuel code MG – Motor Gasoline.	EIA[59], EIA.[60]
	Region	State postal abbreviation for which price, quantity, expenditure and emission values are given (All New England States – CT, VT, RI, MA, ME, NH).	
	Year	Year of the price, quantity, expenditure and emission values.	
	Month	Month of the price, quantity, expenditure and emission values.	
	Sector	Sector name of the price, quantity, expenditure and emission values. Data is available for all sector combined called total energy. Whole fuel consumption is assumed to be for transportation.	
	Price ($/gal)	Monthly Retail Price.	
	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Expenditure ($)	Monthly Retail Expenditure.	Retail Price times Quantity
	Emission Factor (Metric Tons CO_2/gal)	Carbon dioxide emission factor value of 0.008786 (Metric Tons CO_2/gal) for the fuel.	Derived from EPA values.[61]
	Calculated Emissions (Metric Tons CO_2)	CO_2 emission equivalent caused by fuel consumption.	Quantity times Emission Factor.
Monthly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Month		
	Sector		
	Wholesale Price ($/gal)	Monthly Wholesale Price.	

[57] http://www.eia.gov/dnav/pet/TblDefs/pet_pri_allmg_tbldef2.asp
[58] http://www.eia.gov/dnav/pet/TblDefs/pet_cons_prim_tbldef2.asp
[59] http://www.eia.gov/dnav/pet/pet_pri_allmg_a_EPM0_PTA_dpgal_m.htm
[60] http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[61] http://www.epa.gov/cpd/pdf/brochure.pdf

	Quantity (Thousand gal)	Monthly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in the month.	
	Wholesale Expenditure ($)	Monthly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Retail Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	Price ($/gal)	Yearly Retail Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Expenditure ($)	Yearly Retail Expenditure.	Retail Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO_2)		
Yearly Wholesale Data	Fuel	Same as Monthly Retail data.	Same as Monthly Retail data.
	Region		
	Year		
	Sector		
	Wholesale Price ($/gal)	Yearly Wholesale Price.	
	Quantity (Thousand gal)	Yearly Quantity. EIA values in thousand gallons / day are converted into thousand gallons by multiplying quantity with number of days in a year (365).	
	Wholesale Expenditure ($)	Yearly Wholesale Expenditure.	Wholesale Price times Quantity.
	Emission Factor (Metric Tons CO_2/gal)	Same as Monthly Retail data.	Same as Monthly Retail data.
	Calculated Emissions (Metric Tons CO2)		

5.14 Energy Efficiency Program Dataset

Energy Efficiency Program dataset is prepared based on inputs from Rhode Island energy efficiency program administrator's planned and actual annual reports. These reports provide planned annual budgets and the actual expenditure of energy efficiency investments and related savings on a yearly basis filed by efficiency program administrator (National Grid) to Rhode Island Public Utility Commission (RIPUC). The reports are available at RIPUC dockets.[62]

The prepared dataset is divided into Electric Efficiency Programs and Gas Efficiency Programs data subsets. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	**Parameters**	**Description**	**Source Details/Methodology**
Electric Efficiency Programs	State	State postal abbreviation- RI.	Program administrator energy efficiency annual reports (RIPUC Dockets)[63,64,65,66].
	Plan_vs_Actual	Plan represents the budget and projected savings values approved for the respective year. Actual values represent implemented budget and achieved savings for the respective year.	
	Prog_Year	Program Year.	
	Program_Administrator	Program Administrator (PA) that is responsible for management of programs (National Grid for Rhode Island).	
	Sector	Sector name. See the full name of sector codes in the Table 1 below.	
	Program Administration Cost ($)	All costs paid by the programs themselves. This is mostly incentive payments for program participants, but also includes administrative and evaluation costs and performance incentives to PA for achieving certain program goals.	
	Customer Cost ($)	The portion of efficiency projects that is paid by the customer.	
	Total Resource Cost ($)	Sum of Program administration and Customer cost. These will be the total cost of implementing savings/efficiency in the respective year.	
	Non-Electric Benefits ($)	Costs savings to program participants other than electric savings. These could include reduced water, fuel oil, or maintenance costs.	
	ElecSys_Benefits ($)	The sum of capacity benefits, energy benefits and DRIPE (Demand reduction induced price effect).	
	Total Resource Benefits ($)	Sum of non-electric and electric benefits for electric programs and sum of natural gas and non-gas benefits for gas programs. These are the total benefits of achieving savings/efficiency in the respective year. Total resource benefits do not represent net benefits. Net benefits can be calculated by subtracting Total resource cost from	

[62] RI PUC Dockets are available from: http://www.ripuc.org/eventsactions/docket.html
[63] 2009 data is available in Docket 4000: http://www.ripuc.org/eventsactions/docket/4000-NGrid-RevDSMSettle(11-7-08).pdf and http://www.ripuc.org/eventsactions/docket/4000-NGrid-%20YrEndRept(6-1-10).pdf.
[64] 2010 data is available in Docket 4116: http://www.ripuc.org/eventsactions/docket/4116-NGrid-AmendedEEPP(2-8-10).pdf and http://www.ripuc.org/eventsactions/docket/4116-NGrid-Yr-EndReport(5-31-11).pdf.
[65] 2011 data is available in Docket 4209 http://www.ripuc.org/eventsactions/docket/4209-NGrid-2011EEPP(11-1-10).pdf.
[66] 2012 data is available in Docket 4295: http://www.ripuc.org/eventsactions/docket/4295-NGrid-2012EEPP(11-1-11).pdf.

		Total resource benefits.	
	Annual_Energy_Savings (MWh)	Energy savings achieved in the program year.	
	Lifetime_Energy_Savings (MWh)	Energy savings achieved in the lifetime of the program measures installed in a given year.	
	SummerPeak_Demand_Reduction (MW)	Summer peak capacity reduction achieved due to electric efficiency.	
	WinterPeak_Demand_Reduction (MW)	Winter peak capacity reduction achieved due to electric efficiency.	
Gas Efficiency Programs	State	Same as Electric Efficiency Data.	
	Plan_vs_Actual		
	Prog_Year		
	Program_Administrator		
	Sector		
	Program Administration Cost ($)		
	Customer Cost ($)		
	Total Resource Cost ($)		
	Natural Gas Benefits ($)	Avoided natural gas costs in the gas programs.	
	Non-Gas Benefits ($)	Costs savings to gas program participants other than gas savings. This could include reduced water, fuel oil, or maintenance costs.	
	Total Resource Benefits ($)	Same as Electric Efficiency Data.	
	Annual Energy Savings (MMBTU)		
	Lifetime Energy Savings (MMBTU)		

Sector code	**Full name**
LI	Low-Income
R	Residential, excluding low-income
CI	Commercial & Industrial
Total	Total

5.15 Regional Greenhouse Gas Initiative (RGGI) Dataset

The Regional Greenhouse Gas Initiative (RGGI) dataset is prepared using auction data from RGGI Inc.[67] and emission data from RGGI, Inc. CO_2 Allowance Tracking System (RGGI-COATS)[68]. The RGGI States report results on each CO_2 Allowance Auction. The Rhode Island cap data comes from: AIR POLLUTION CONTROL REGULATION NO. 46: CO_2 Budget Trading Program, section 46.4. Regional allowance budget (RGGI cap) is the sum of state allowance budgets established in enabling legislating and regulations. RGGI, Inc.'s provides oversight, administration and technical assistance to support the development and implementation of CO_2 Budget Trading Program for all RGGI States - Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.[69] All the fossil fuel-fired plants with a capacity of 25 MW or greater located within the RGGI states are regulated by the program.[70]

The prepared dataset is divided into Rhode Island RGGI Auction data, Rhode Island RGGI Facility Emissions data and Cap-Level data subsets. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	Parameters	Description	Source Details/Methodology
Rhode Island RGGI Auction Data	Auctions No.	Quarterly Auction number for RGGI Allowances.	RGGI Inc.
	Date	Date of Auction.	
	Year	Year of Auction.	
	Month	Month of Auction.	
	Current Control Period Allowances Sold	Allowances sold for the 3-year compliance period during which auction is held.	
	Current Control Period Proceeds	Revenue from the sale of allowances sold for the 3-year compliance period during which auction is held.	
	Future Control Period Allowances Sold	Allowances sold for the 3-year compliance period subsequent to the compliance period during which auction is held.	
	Future Control Period Proceeds	Revenue from the sale of allowances sold for the 3-year compliance period subsequent to the compliance period during which auction is held.	
	Total Allowances Sold	Sum of Current and Future Control Period Allowances	

[67] http://rggi.org/market/co2_auctions/results
[68] https://rggi-coats.org/eats/rggi/
[69] http://rggi.org/rggi
[70] http://www.rggi.org/design/overview/regulated_sources

		sold.	
	Total Proceeds	Sum of revenue from sales of Current and Future Control Period Allowances.	
	Clearing Price (First)	Clearing price for current control period allowances.	
	Clearing Price (Second)	Clearing price for future control period allowances.	
Rhode Island RGGI Facility Emissions	State	State postal abbreviation-RI.	RGGI-COATS.
	Year	Year of Auction.	
	Qtr	Quarter Number.	
	Source Name	Name of source (power facility) in RGGI program.	
	ORIS Code	EPA Plant ID. Same as EIA Facility ID.	
	Control Period	Compliance period of 3 years.	
	CO₂ Mass (Short Tons)	Emissions.	
	Locational Coordinates (Latitude, Longitude)	Latitude and Longitude values of the facility.	EIA-860, 2010 data requested from EIA. Some points were modified to update position information.
Cap-Level	Year	Year of Auction.	Rhode Island Regulation[71], RGGI Inc.[72]
	RI Allowance Budget	Rhode Island emissions cap.	
	Regional Allowance Budget (this is the program cap)	RGGI overall program cap for following states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont	

[71] http://www.dem.ri.gov/pubs/regs/regs/air/air46_08.pdf
[72] http://rggi.org/design/regulations

5.16 Heating Fuel Mix Dataset

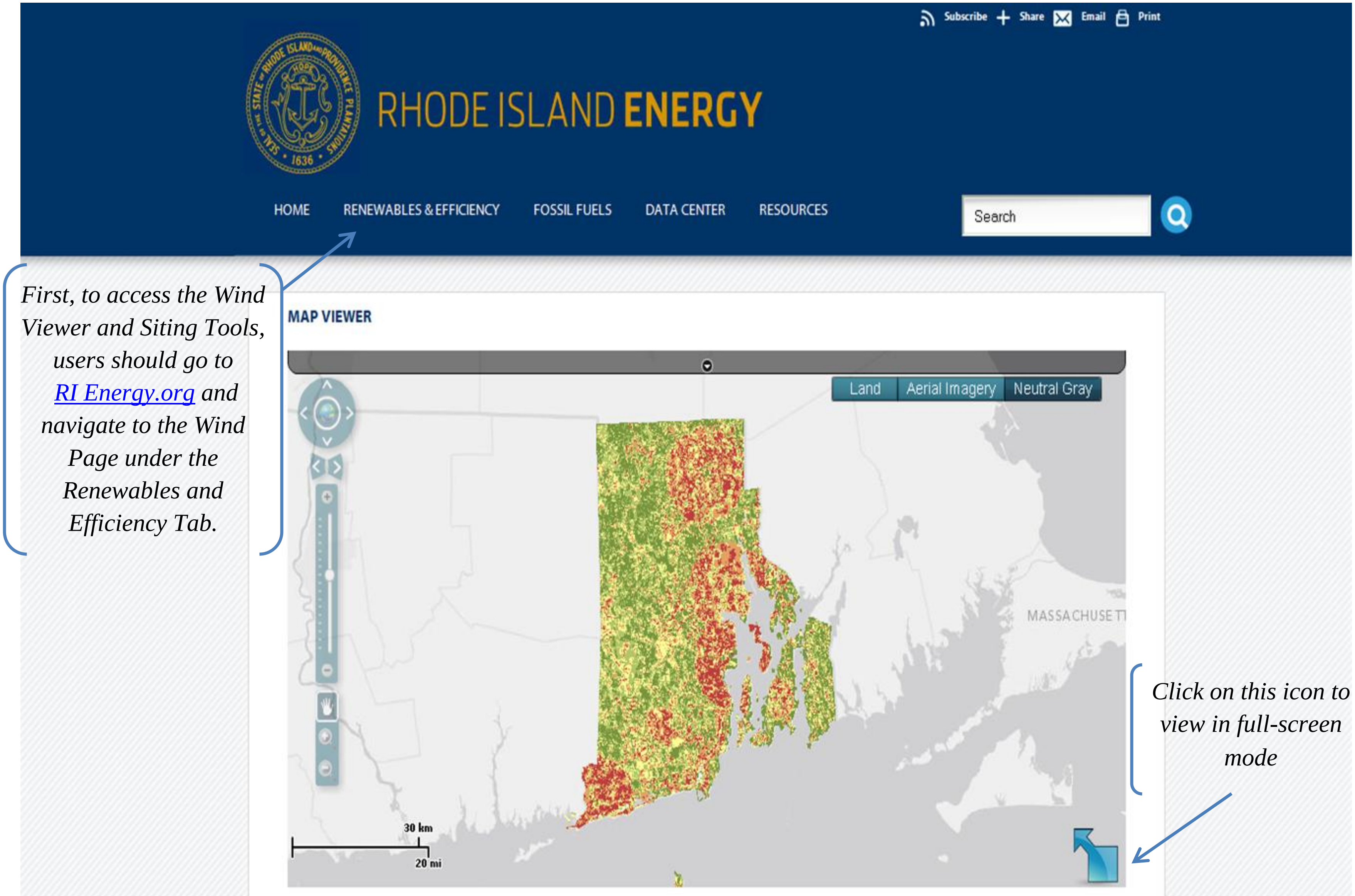
Heating Fuel Mix dataset is prepared using the United States Census Bureau's 'Census 2000' data. The agency collected this data and compiled it in Summary File 3 (SF3).[73] The information is developed based on questions asked of a sample of all people and housing units about heating fuels usage[74]. Data set specifications by column headers are provided in the following table:

SPECIFICATIONS

Dataset	**Parameters**	**Description**	**Source Details/Methodology**
Heating Fuel Mix	RI Zip Codes	Rhode Island Zip Codes.	Census 2000.[75]
	Total (H.Units)	Total house units.	
	Utility gas (H.Units)	House units which use Natural Gas.	
	Bottled, tank, or LP gas (H.Units)	House units which use Propane (LPG).	
	Electricity (H.Units)	House units which use Electricity.	
	Fuel oil, kerosene, etc. (H.Units)	House units which use Heating Oil.	
	Coal or coke (H.Units)	House units which use Coal.	
	Wood (H.Units)	House units which use Wood.	
	Solar energy (H.Units)	House units which use Solar.	
	Other fuel (H.Units)	House units which use Other fuel.	
	No fuel used (H.Units)	House units which do not use any fuel.	
	Total (%)	Percentage of total House units.	
	Utility gas (%)	Percentage of House units which uses Natural Gas.	
	Bottled, tank, or LP gas (%)	Percentage of House units which uses Propane (LPG).	
	Electricity (%)	Percentage of House units which uses Electricity.	
	Fuel oil, kerosene, etc. (%)	Percentage of House units which uses Heating Oil.	
	Coal or coke (%)	Percentage of House units which uses Coal.	
	Wood (%)	Percentage of House units which uses Wood.	
	Solar energy (%)	Percentage of House units which uses Solar.	
	Other fuel (%)	Percentage of House units which uses Other fuel.	
	No fuel used (%)	Percentage of House units which do not uses any fuel.	

[73] http://www2.census.gov/census_2000/datasets/Summary_File_3/
[74] http://www.census.gov/prod/cen2000/doc/sf3.pdf
[75] http://factfinder2.census.gov/main.html

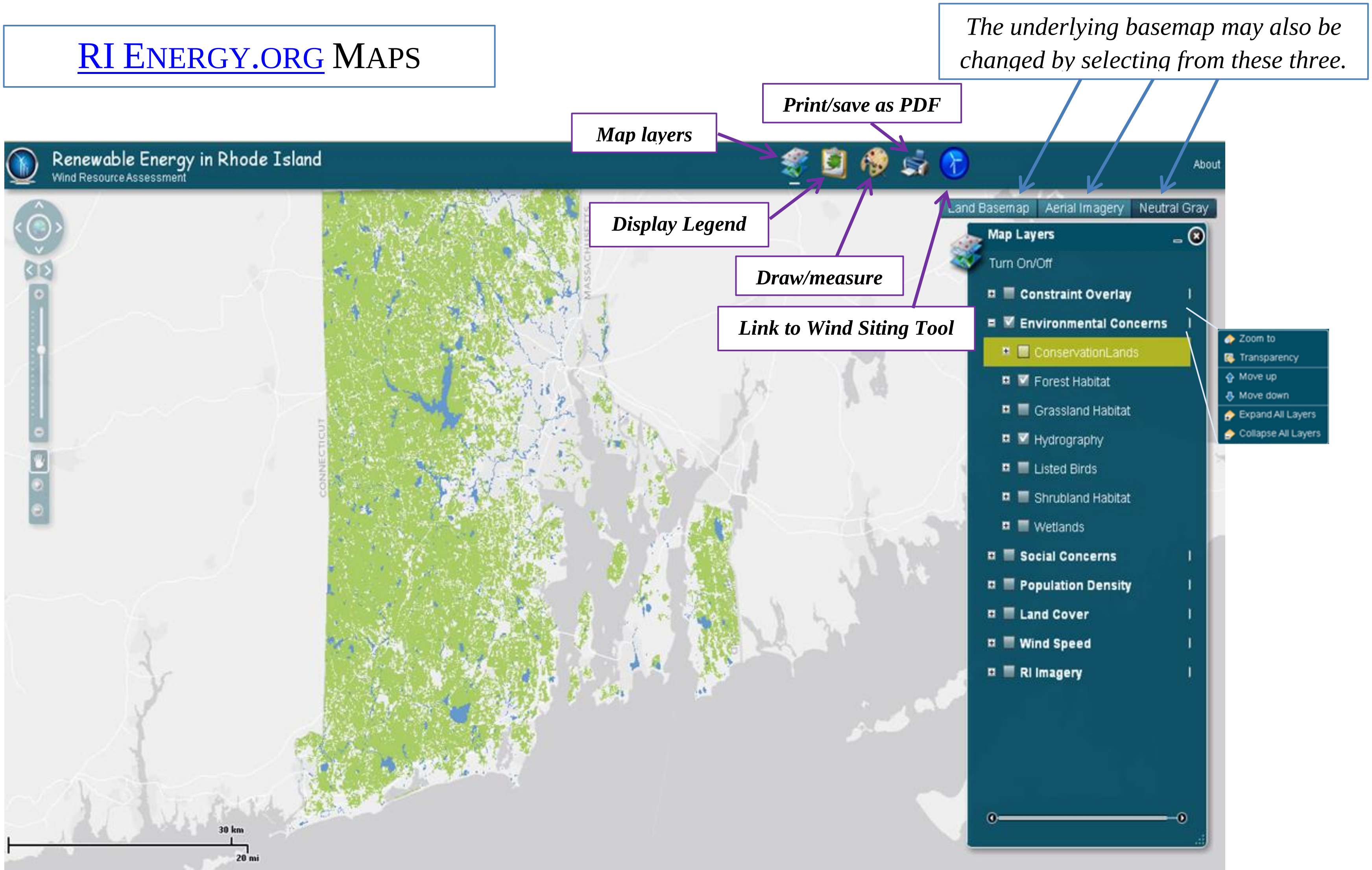
RI ENERGY.ORG TUTORIAL: WIND CASE STUDY



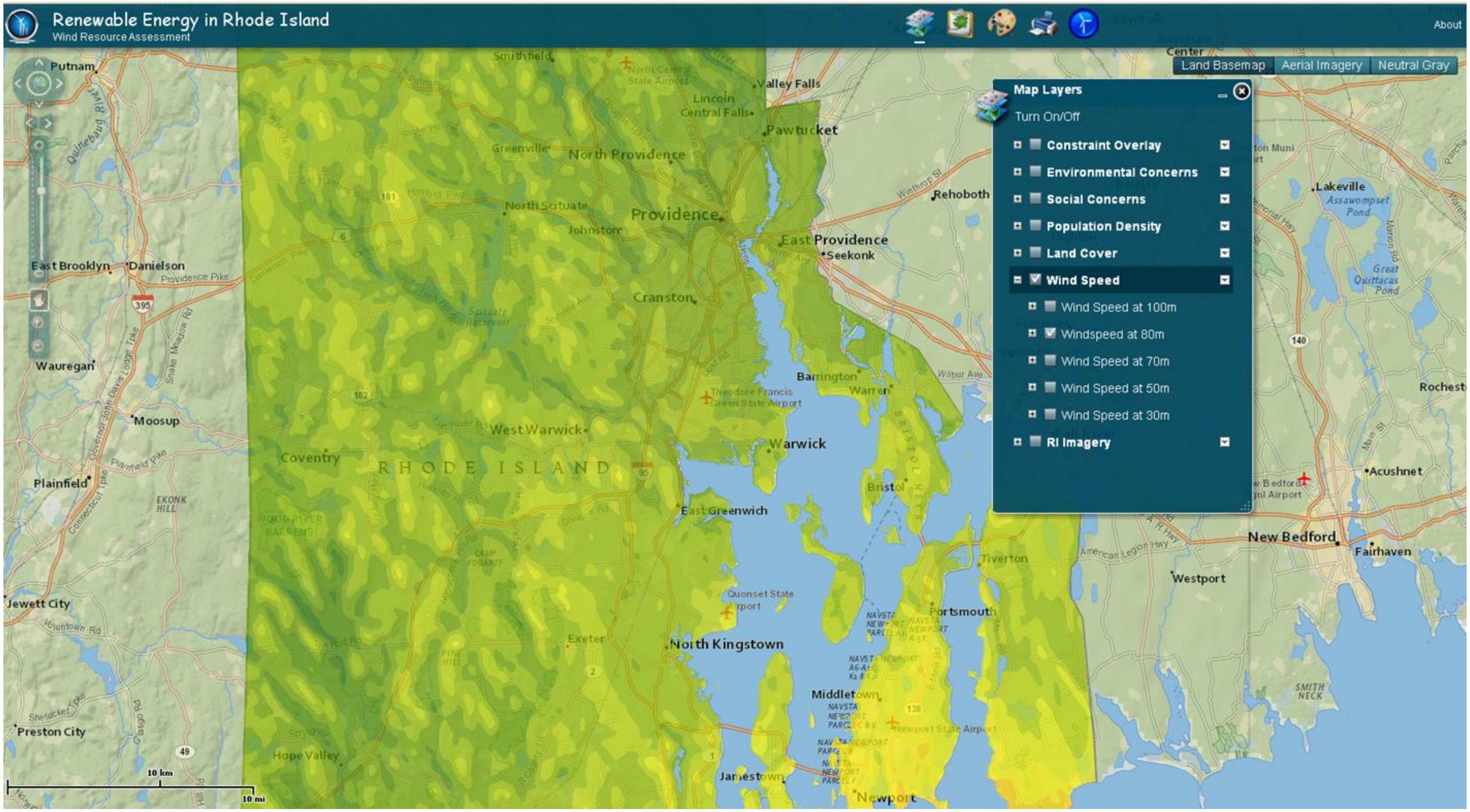
First, to access the Wind Viewer and Siting Tools, users should go to RI Energy.org and navigate to the Wind Page under the Renewables and Efficiency Tab.

Click on this icon to view in full-screen mode

RI ENERGY.ORG MAPS

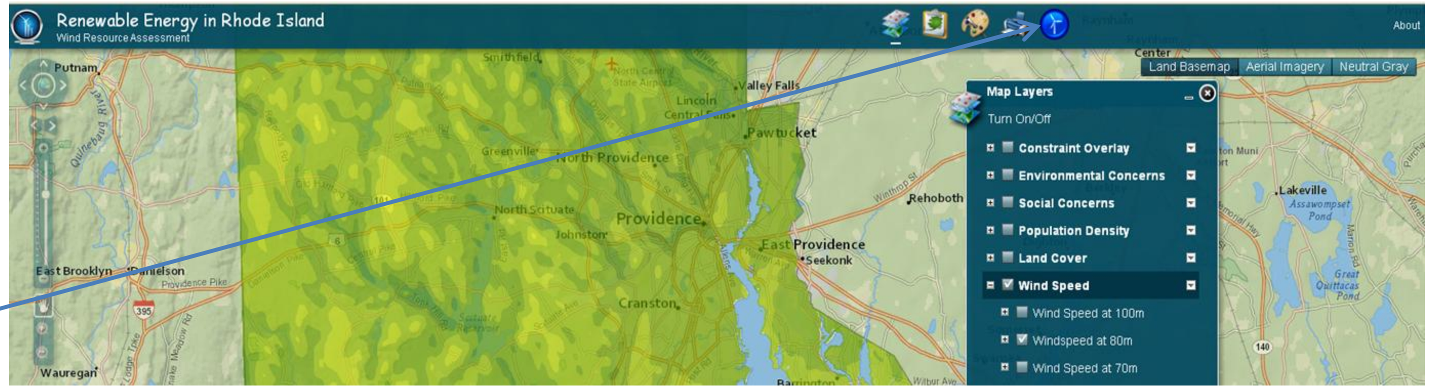


Users can turn on or off any of the layers described in the Wind Energy Chapter of Volume 1 or in Grilli et al. (2012) by checking or unchecking the boxes to the left of the listed layer. Both the category and the particular layer of interest must be checked in order for it to be displayed.

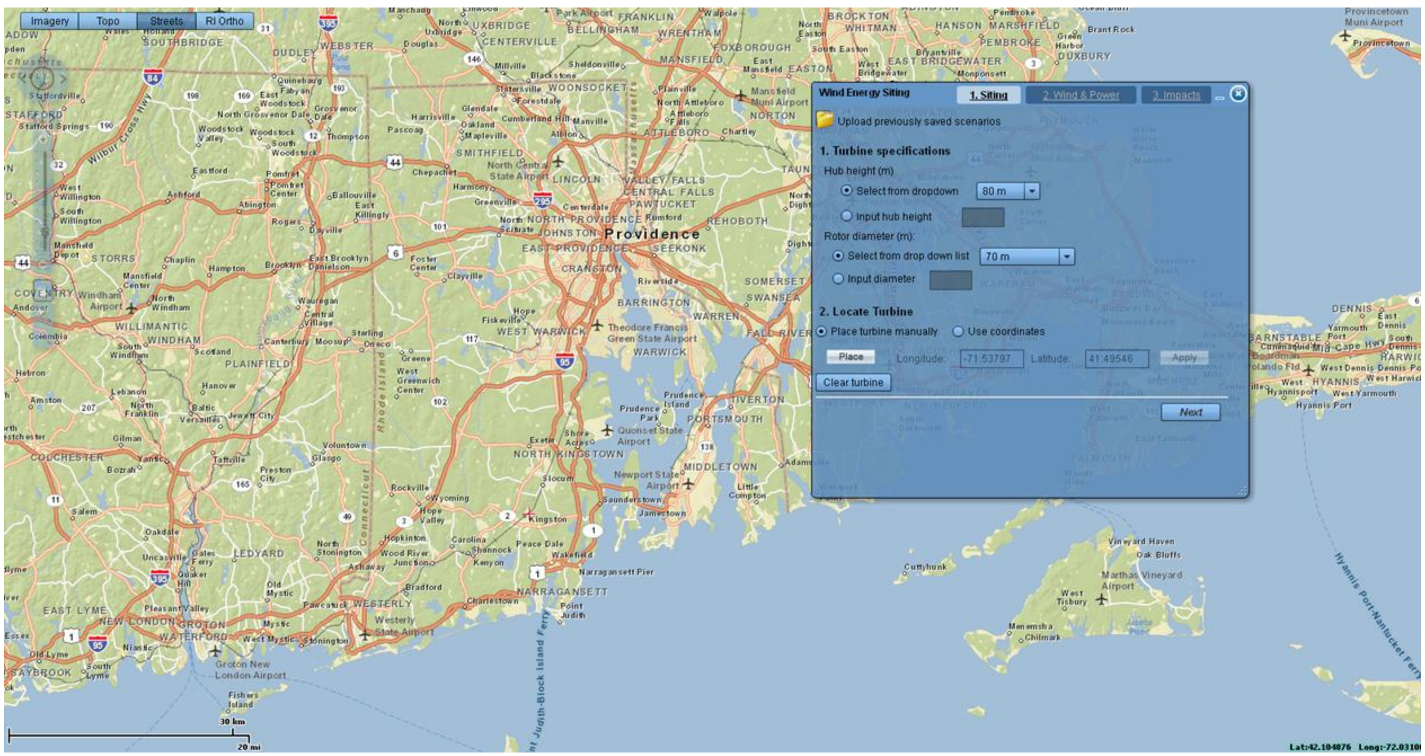


Layers available for display include: conservation lands; habitat (forest, grassland, shrubland); hydrography (ponds, lakes, rivers); Areas with potential endangered or threatened bird species; wetlands ; ambient noise levels (modeled based on land use); airports; historic sites and districts; impervious surfaces (roads, bridges, parking lots); communication towers; population density; land cover; and wind speeds at (30m, 50m, 70m, 80m, and 100m).

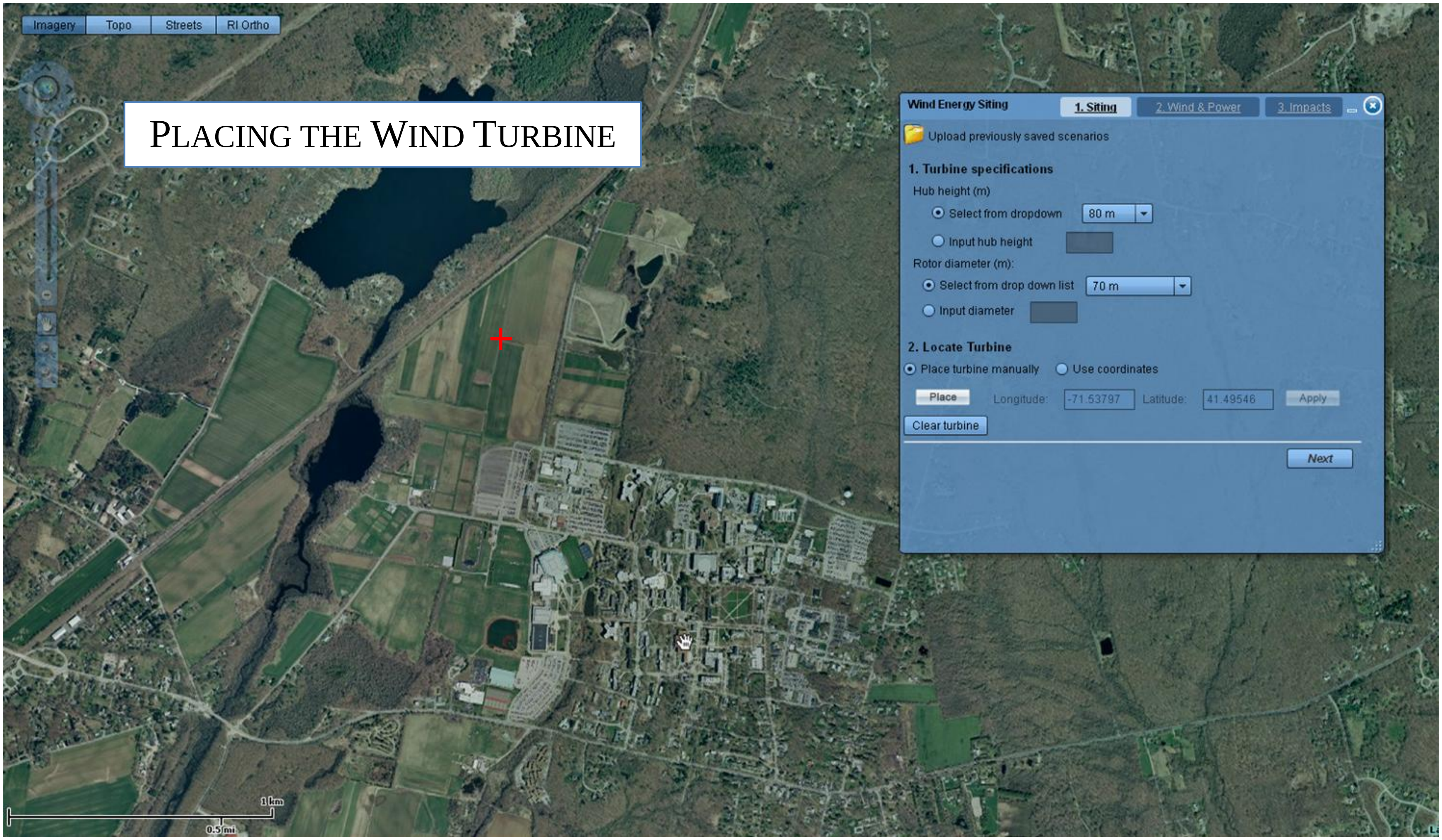
To access the wind siting tool from RI Energy.org, simply click on the icon of the turbine at the top of the wind viewer.



THE WIND SITING TOOL

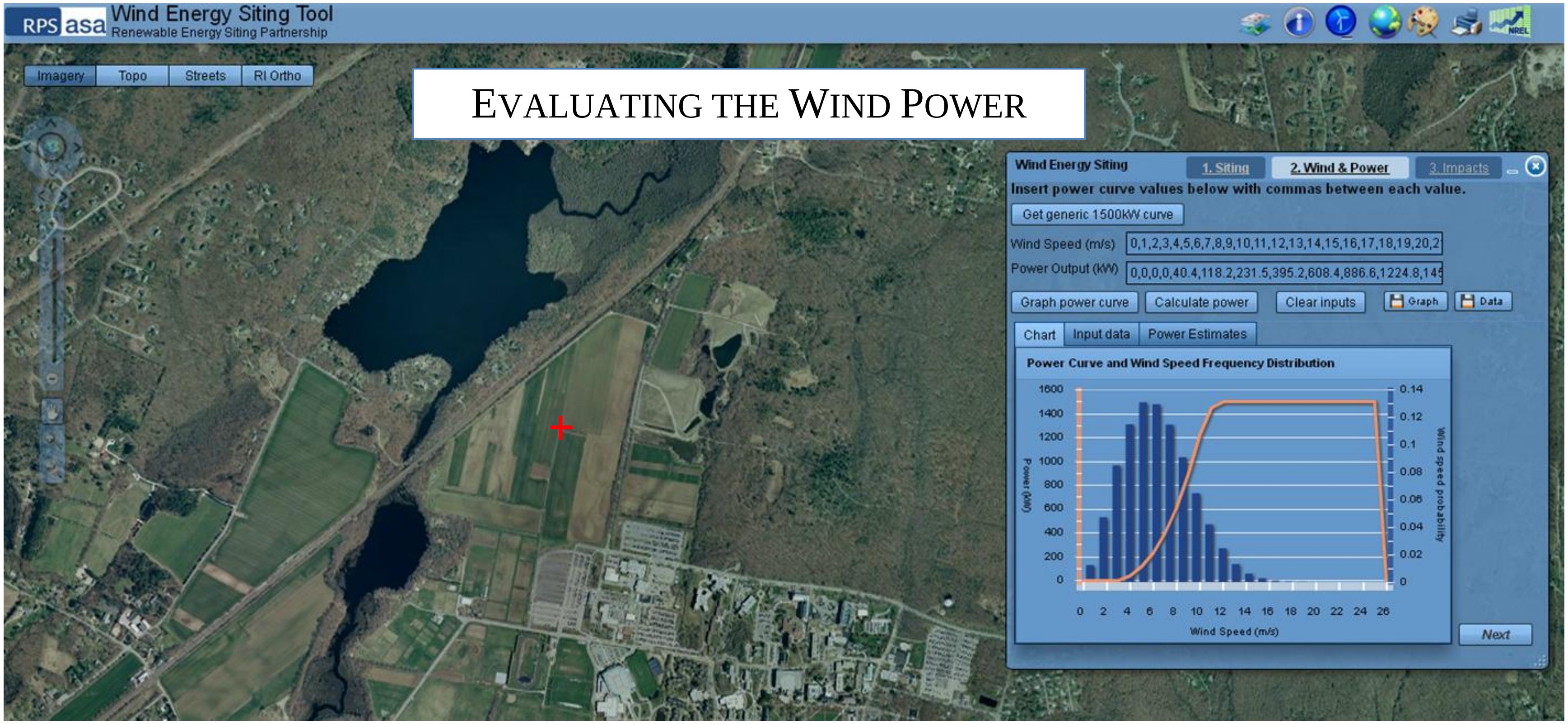


Once the wind siting tool is open, the first step in the siting tool is identifying where the turbine will be sited and what size technology will be used. The user must input the hub height and rotor diameter of the turbine in meters. Next, the user must either manual place the turbine at its location within the map, or input the corresponding latitude and longitude for the project site.

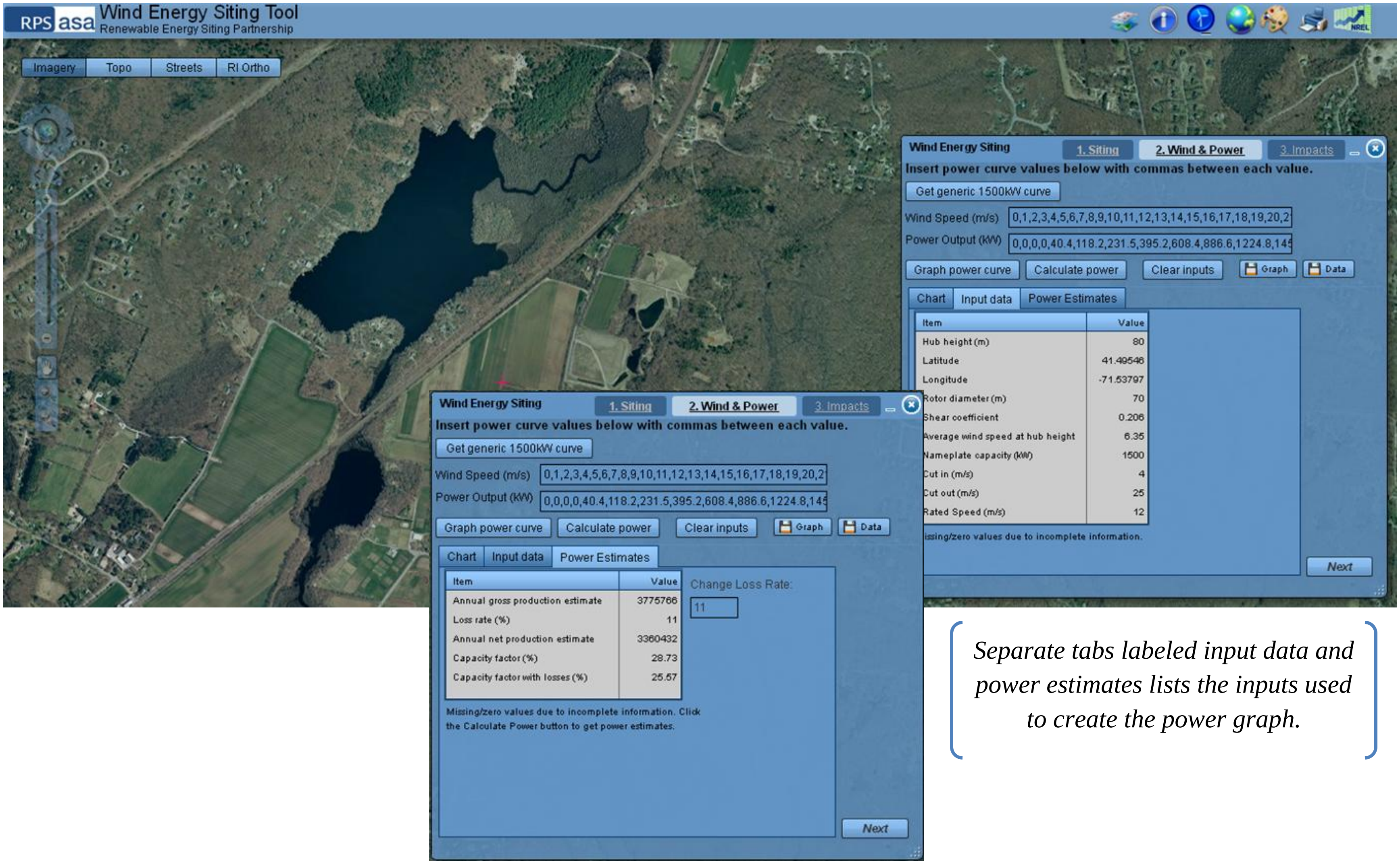


*In order to illustrate the utility of the Wind Siting Tool developed for the RESP, a case study is presented here. This case study is a fictitious example meant to demonstrate the types of inputs and results that can be obtained from this tool. For this example, we examined placing an **80 m turbine**, with a **70 m rotor diameter** in one of the turf fields near the URI Kingston campus. The user can then click 'Next' to move onto the Wind & Power portion of the siting tool.*

EVALUATING THE WIND POWER



The Wind & Power window allows users to view a power curve based on a sample 1.5 MW turbine or by inputting power output data based on the actual turbine that is planned for the site. The graph will display the power curve, as well as the frequency distribution of wind speeds for the site selected. Separate tabs labeled input data and power estimates lists the inputs used to create the power graph. For this site, the highest frequency wind speeds are below 6m/s.

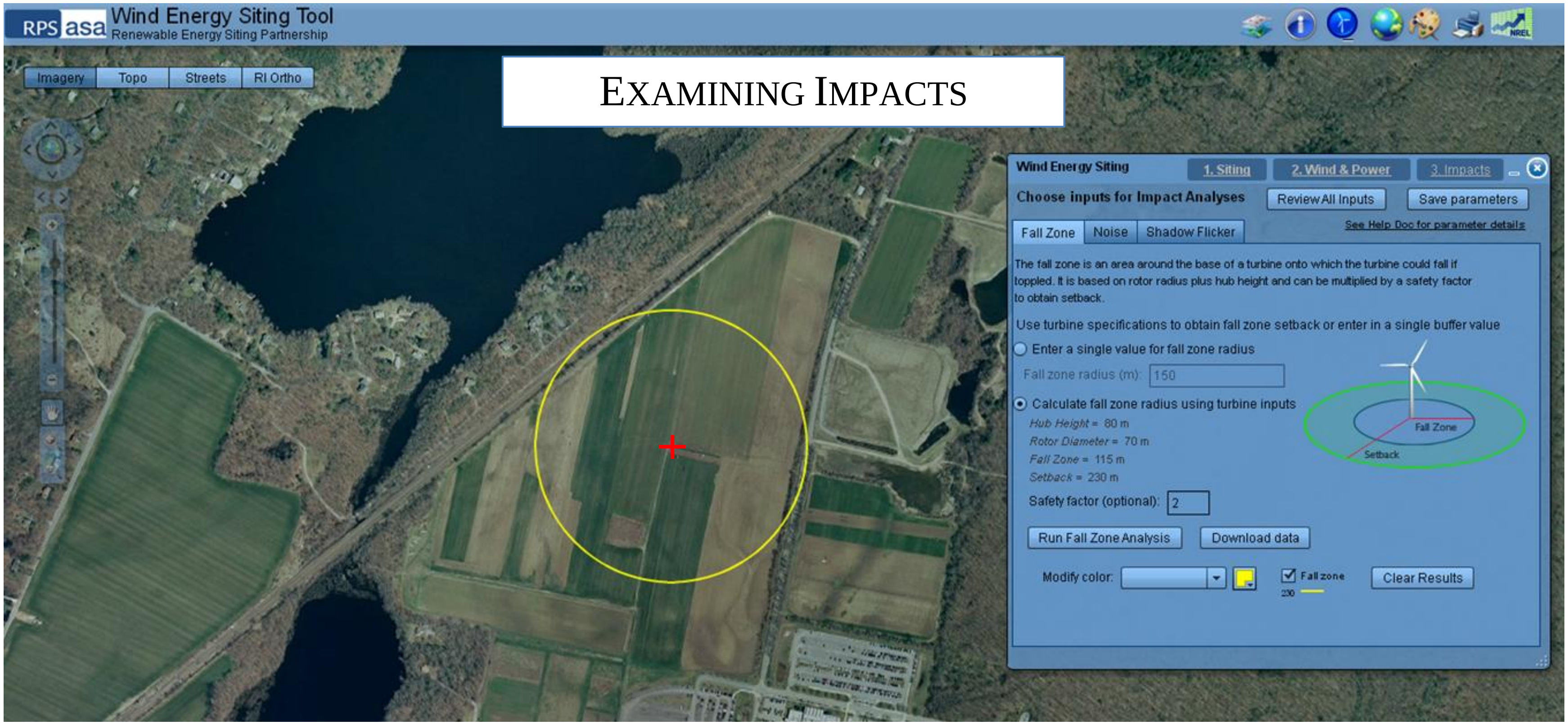


Separate tabs labeled input data and power estimates lists the inputs used to create the power graph.

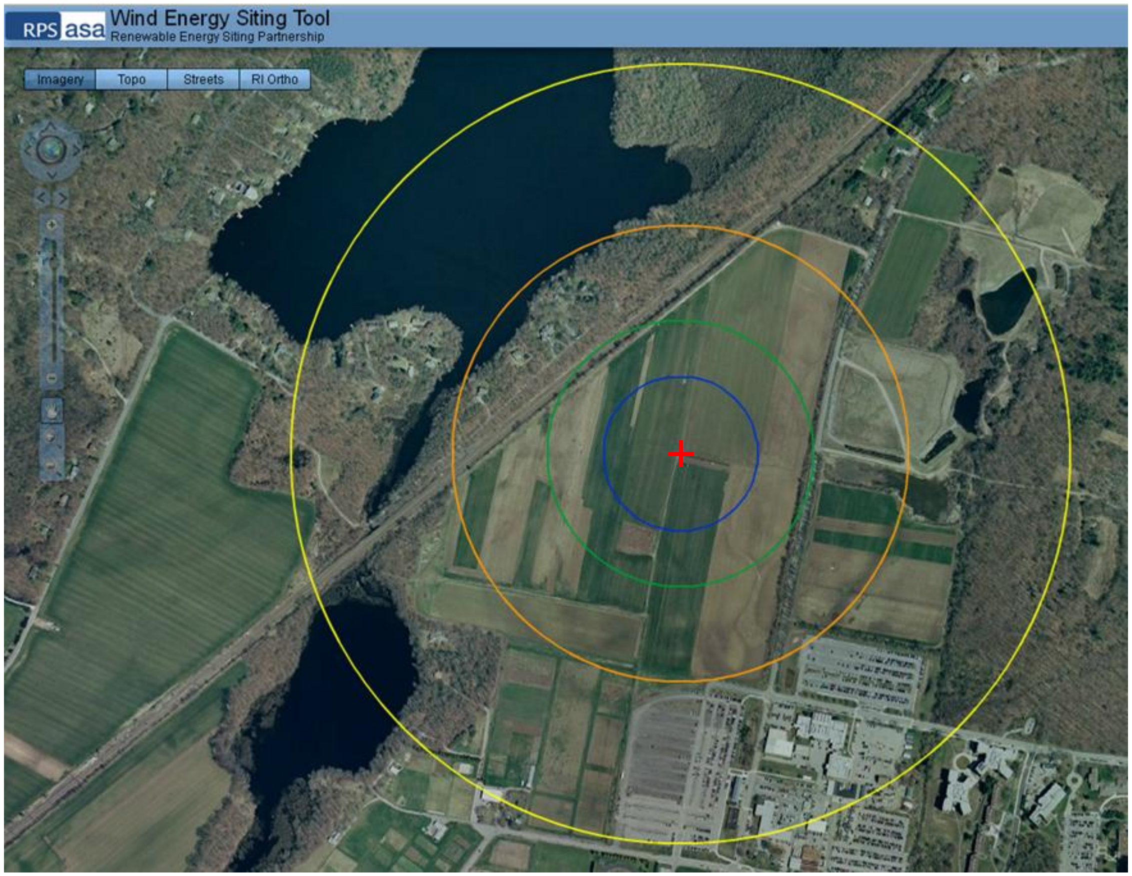
Based on the inputs used and the wind resources at the site selected it is estimated that the annual gross production is equal to 3,775,766 kilowatt hours (kWh). Assuming a loss rate of 11% annual net production for this turbine is estimated at 3,360,432 kWh or 3.4 GWh.

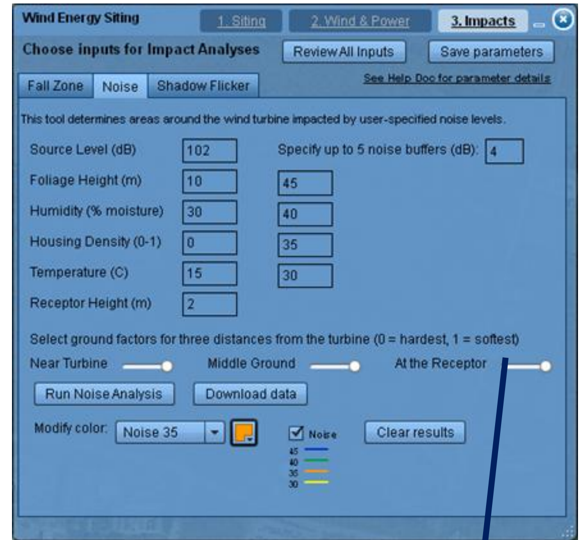
The 'Next' button moves the user to the Impact Analysis portion of the siting tool, where safety setbacks for fall zones or other structural failures can be mapped, as well as contours depicting noise levels and shadow flicker impacts.

EXAMINING IMPACTS



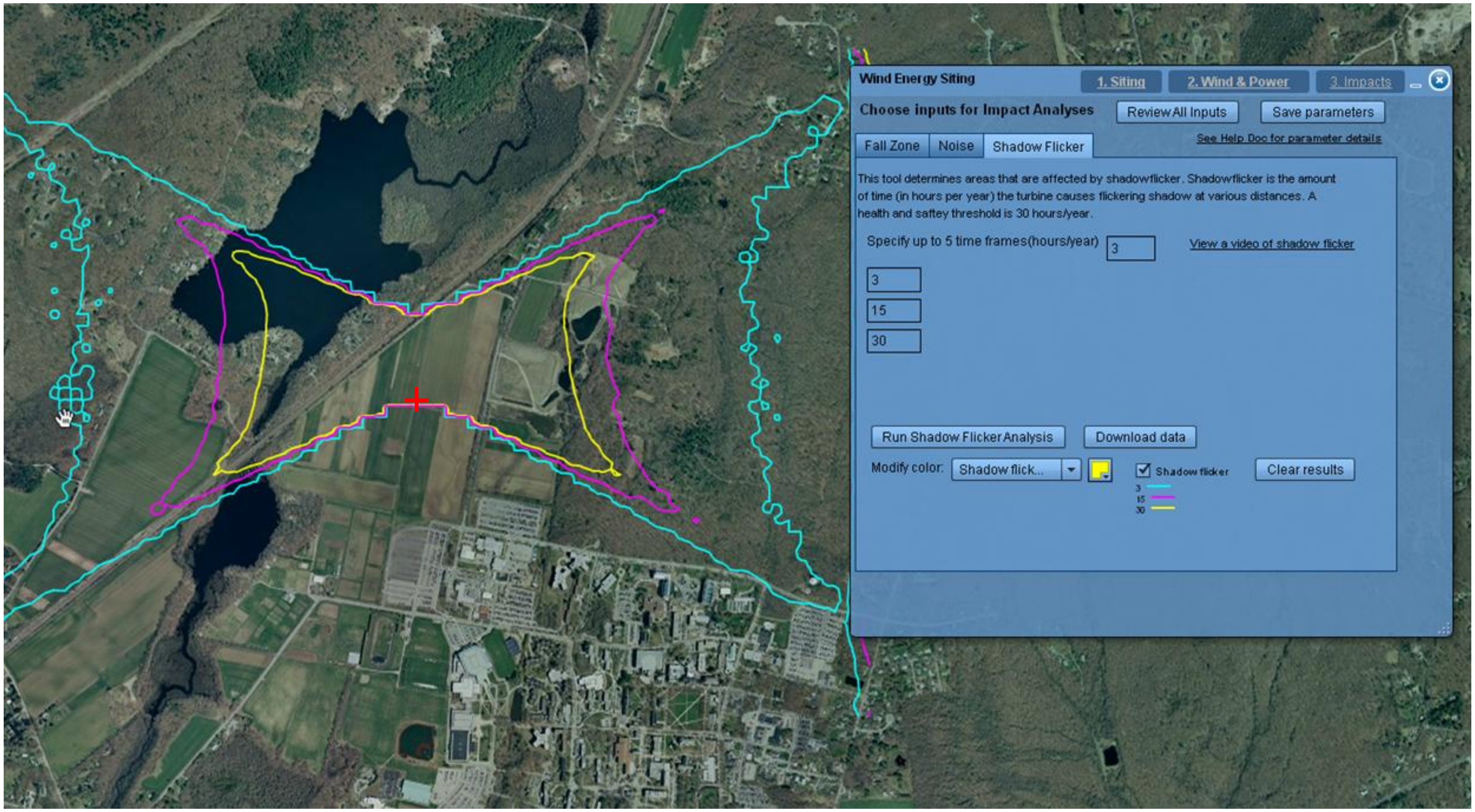
*Fall zones can be mapped either using a particular setback distance (e.g. 150 meters) or by using some distance based on the turbine's size. For example, this imagine illustrates what the fall zone setback distance would be if 2*the turbine's total height or 2*(80m+35m)= 230 m.*





Type of Ground	Example	Ground factor
Hard	Low porosity ground (paving, water, ice, concrete etc.)	0
Porous	Ground suitable for growth of vegetation (ground covered with grass, trees, vegetation)	1
Mixed	Mix of hard and soft ground	Between 0 and 1

The Noise tab allows contours to be mapped around the turbine representing various noise levels, allowing the user to see which areas, houses or buildings may be affected by noise. The user can specify: the source level (the wind turbine noise level at the turbine, in this case its 102 dB); various environmental parameters (such as foliage, humidity, temperature); relative housing density (0= rural settings and 1=high density of housing); ground factors (either hard or soft, see Table above); and up to 5 noise levels in dB to be mapped. A more detailed description of the underlying model used is provided in Potty and Miller (2012) in Volume II of the RESP report.



Finally, areas potentially impacted by shadow flicker can be mapped by the siting tool simply by entering up to 3 thresholds of hours of shadow flicker per year to be mapped. These shadow flicker contours represent the theoretically worst case scenarios (i.e. a situation where there is always sunshine during the day to create shadows, the turbine is always spinning, the terrain is flat , and when the wind direction is always favorable for generating shadow at the receiver). Actual occurrence of shadow flicker will be less than these worst case scenarios, however they are useful for planning purposes. For more information on this shadow flicker model see Potty and Miller (2012) in Volume II of the RESP report.

RENEWABLE ENERGY SITING PARTNERSHIP

CHAPTER 5. STAKEHOLDER PROCESS AND PUBLIC ENGAGEMENT

Table of Contents

List of Tables

STAKEHOLDER PROCESS AND PUBLIC ENGAGEMENT

The RESP stakeholder process was built on the recognition that scientific research offers only a partial toolkit for achieving appropriate siting for wind energy facilities. Public input into the siting process is equally vital, particularly in a small state like Rhode Island where energy installations must inevitably border and overlap with neighborhoods, workplaces, and recreational settings. When sited appropriately, renewable energy can provide public benefits like local jobs and reduction in the usage of fossil fuels responsible for greenhouse gas emissions. However, if sited in a way that ignores the knowledge and concerns of local residents, the negative effects of renewable energy installations could cancel out these benefits. To avoid such pitfalls and enable informed decision making all around, the RESP stakeholder process and public engagement framework incorporated public input from the start.

The goals of the RESP stakeholder process were: (1) to give the public a central role in guiding the RESP process, through collaboration with RESP staff in issue identification, information synthesis, and development of final products; (2) to listen to public reservations and inquiries regarding the effects of new renewable energy in the state, and respond to them using the best available scientific knowledge assembled by RESP staffers and scientists, (3) to enable dialogue and mutual learning among stakeholders, government officials, and scientists, and (4) to catalog public knowledge and concerns about renewable energy development and help state agencies incorporate this information into siting guidelines. The stakeholder and public engagement process assured that the RESP was not only a scientific exercise and a basis for policy decisions, but also an embodiment of public needs and visions regarding renewable energy in Rhode Island.

The RESP stakeholder and public engagement process brought together a diverse and well-rounded group of key constituencies by reaching out to two core groups of people simultaneously. The first group included organizations deemed to be essential in developing and implementing renewable energy siting strategies in the state. These included municipalities, relevant state and federal agencies, regional planning councils, non-governmental organizations, chambers of commerce, historical societies, universities, tourism groups, utilities, land trusts, and the Narragansett Indian Tribe. The RESP coordination team reached out to over 250 of these organizations to solicit their participation in the RESP process. The second key group was self-selecting, and included members of the public and the business community. The RESP coordination team reached out to this broad group by publicizing stakeholder participation opportunities on the RESP website and listserv. While the two groups came to the process though different channels, both were indispensable to creating a transparent and objective RESP process meeting the needs of all Rhode Islanders.

1. PROJECT TIMELINE

The Renewable Energy Siting Partnership process involved the public from beginning to end. The role of stakeholders and the public evolved as the RESP process advanced from issue identification to information synthesis to development of final products. At every point along the way, stakeholder participation represented an indispensable part of RESP practices and outputs.

1.1 Phase I: Issue Identification & Assessment (September – November 2011)

The purpose of engagement with stakeholders during the initial phase of the RESP was to identify issues of public concern regarding the siting and management of land-based renewable energy projects. During this phase, stakeholders located existing research and data, contemplated past renewable energy projects in the state and elsewhere, and steered the course of the RESP research so as to maximize its relevance to public concerns.

The main issues of concern identified by stakeholders during this phase included: health impacts of wind turbines, visual impacts of wind turbines, impacts of wind turbines on property values, effects of natural disasters, maintenance requirements for renewable energy facilities, financing for renewable energy facilities, decommissioning of renewable energy facilities, economic modeling of the costs and benefits of renewable energy facilities, potential use of open space to host renewable energy projects, questions on the cap integrity of landfills, interest in pursuing methane capture at landfills, interest in geothermal energy, a perceived need to balance protection of wildlife habitat with economic needs, and the need for regional cooperation.

1.2 Phase II: Information Synthesis & Communication (December 2011 – January 2012)

During this phase, RESP staff and stakeholders took part in a joint learning process wherein staffers communicated technical responses addressing the issues of concern identified by stakeholders during Phase I. As part of this endeavor, RESP staff shared preliminary results of the original research conducted by URI scientists under the auspices of the RESP.

Whereas in Phase I, the role of stakeholders was to ask questions, in Phase II, it was to learn, respond, and critique. Learning by stakeholders during the RESP process not only equipped stakeholders to better weigh in on RESP guidelines, but also created a network of informed citizens throughout Rhode Island that will be vital to assuring that the lessons learned during the RESP have continuing positive influence as renewable energy projects are implemented in the state.

1.3 Phase III: Development of Final Products (February – July 2012)

During this phase, the RESP team finalized various research products and helped state agencies develop specific siting and management guidelines for renewable energy development, including a RIDEM document on low-head hydropower considerations and a Statewide Planning Program wind energy guidance document. The role of stakeholders during this phase was to scrutinize RESP research findings for accuracy, provide input on how to incorporate findings into practical tools, and to provide input on appropriate siting and management guidelines based on these findings.

1.4 Phase IV: Formal Public Comment & Review (July 2nd through August 31 2012)

An approximately 60-day public comment period allowed all stakeholders and members of the public to review all RESP reports and web components. All comments submitted have been responded to by the RESP team and posted online. Final products were completed and released in December 2012, along with all comment responses.

2. STAKEHOLDER EVENTS AND WORKING GROUPS

The RESP created seven different forums to engage the public and stakeholders in providing advice on renewable energy siting in Rhode Island. These included a series of monthly general stakeholder meetings, several field trips to current renewable energy sites, establishment of a Municipal Working Group, establishment of a Wind Energy Siting Working Group, a traveling library lectures series, two targeted hydropower stakeholder workshops, and a Renewable Energy Day. Six of these forums are discussed in detail below; targeted hydropower stakeholder workshops are discussed in Section 3.5 of this report.

2.1 Monthly Stakeholder Meetings

From September 2011 – March 2012, the RESP hosted a total of seven monthly general stakeholder meetings. These meetings were open to all members of the public, and were advertised through the RESP website and listserv. In addition, the RESP team issued personalized invitations to over 250 organizations and agencies with particular relevance to the siting of renewable energy facilities, including local chambers of commerce, state and federal agencies, historical societies, land trusts, municipalities, non-governmental organizations, tourism associations, utilities bodies, and the Narragansett Indian Tribe. Attendance at each stakeholder meeting ranged from about 55 to 85 people, with participants representing a wide and diverse range of interests (see Ch. 5 Table 1). Meetings were held on Thursday evenings at the University of Rhode Island Bay Campus. A full schedule of meetings and topics is given in Ch. 5 Table 2.

Communication at RESP stakeholder meetings flowed in multiple directions. Meetings simultaneously provided a forum for RESP researchers to communicate their methods and findings to members of the public, and for members of the public to learn, ask questions, voice concerns, and weigh in on important issues presented by researchers. The general format for each meeting began with a RESP project update, continued with a series of RESP researcher lectures, and culminated in a free-flowing group discussion facilitated by one of the RESP team leaders.

Ch. 5 Table 1. Participants in RESP Monthly Stakeholder Meetings

Renewable Energy Businesses	
Apex Wind	Bristol Wind Power
Conanicut Energy	E2SOL LLC
Endless Energy	Essex Partnership
NERC Renewables	Newport Solar
NEXAMP	Point Energy Solutions
Real Goods Solar	Rhode Power
rTerra	Solar Canopy LLC
Soltas Energy	SPG Renewables
Wind Energy Development LLC	Alteris Renewables
CurveWater LLC	
Other Businesses	
Block Island Power Company	Deep Blue Technologies
EA Engineering	East Providence Fuel Oil Company
ESS Group	Fall River Mill Owners Association
Guardian Fuel and Energy	Newport Harbor Corporation
Newport Waterfront Events	Providence Water Supply Board
Schneider Electric	Tech Comm Partners
VHB	3 Sisters Design
Filarski/ architecture + planning + research	Grubb and Ellis Real Estate
Applied Science Associates	DeWayne Allen Associates
Nongovernmental Organizations	
Aquidneck Island Land Trust	Audubon Society of Rhode Island
Blackstone River Watershed Council	Conservation Law Foundation
Wood-Pawcatuck Watershed Association	Energy Consumers Alliance of New England
Ocean State Clean Cities	R.I. Land Trust Council
Save the Bay	Environment Northeast
The Nature Conservancy	People's Power and Light
Woonasquatucket River Watershed Council	Northeast Sustainable Energy Association
Environmental Council of R.I.	R.I. Rivers Council
Stillwater Preservation Conservancy	
Universities	
Bryant University	Roger Williams University
Rhode Island School of Design	University of Rhode Island

Municipal and Regional Entities	
Barrington Renewable Energy Committee	Newport Energy and Environment Commission
City of Warwick	Cranston Public Schools
East Bay Energy Consortium	Chariho Middle School
North Kingstown High School	Town of Charlestown
Town of East Greenwich	Town of Jamestown
Town of Johnston	Town of Middletown
Town of Narragansett	Town of North Kingstown
Washington County Regional Planning Council	Aquidneck Island Planning Commission
State Entities	
Division of Planning	Office of Energy Resources
Representative Teresa Tanzi	Representative Larry Ehrhardt
Senator Jack Reed	Department of Environmental Management
Federal Entities	
U.S. Navy	
U.S. Fish and Wildlife Service	
U.S. Department of Agriculture	
Members of the R.I. Public	

Ch. 5 Table 2. RESP General Stakeholder Meeting Schedule

Stakeholder Meeting #1, September 15, 2011 (Attendance: ~80)	
<u>Purpose of meeting</u> To introduce participants to the RESP project; to discuss how the RESP builds upon past and existing initiatives; and to identify stakeholder expectations, issues, and concerns.	<u>Activities</u> Overview of wind, solar & hydropower energy siting; discussion of plans for an online energy information & data hub; and progress update on R.I. Statewide Planning Program's Wind Energy Guidelines and how they connect to the RESP.
Stakeholder Meeting #2, October 6, 2011 (Attendance: ~80)	
<u>Purpose of meeting</u> To present information on potential impacts of renewable energy on birds and bats in Rhode Island; and to further discuss the RESP stakeholder process, stakeholder issues and concerns received to date, & expected project outcomes.	<u>Activities</u> Assessment of the potential impacts renewable energy on birds and bats in Rhode Island
Stakeholder Meeting #3, November 3, 2011 (Attendance ~80)	
<u>Purpose of meeting</u> To review the status of the RESP effort to generate renewable energy maps and an online	<u>Activities</u> Overview of URI Environmental Data Center

viewer for maps and data; to present information on wind, solar, and hydropower resource assessments; and to further discuss the RESP stakeholder process, stakeholder issues and concerns received to date, & expected project outcomes.	activities; presentation on creating a map tool for evaluating land-based renewable energy potential: wind, solar, and hydropower; overview of R.I. wind resource assessment.
Stakeholder Meeting #4, December 1, 2011 (Attendance: ~70)	
Purpose of meeting To present information on wind energy acoustic impact assessment; and to present an overview of renewable energy analytics and project economics.	Activities Presentation of fundamental acoustics and wind turbine noise issues; presentation of economics of renewable energy projects.
Stakeholder Meeting #5, January 12, 2011 (Attendance: ~85)	
Purpose of meeting To present an overview of potential visual impacts of wind energy infrastructure; to present information on shadow flicker and electromagnetic interference related to wind energy infrastructure; and to discuss a process for evaluating impacts on property values for parcels adjacent to wind energy infrastructure.	Activities Presentation on valuating visual impacts of wind energy infrastructure; presentation on wind turbine shadow flicker & electromagnetic interference; stakeholder-led shadow flicker case study from Portsmouth, RI; discussion of visual impacts of wind turbines; discussion of property value impacts of wind turbines; presentation of draft RESP table of contents.
Stakeholder Meeting #6, February 2, 2011 (Attendance: ~55)	
Purpose of meeting To introduce RESP online resource deliverables; to present an overview of research by the Rhode Island Energy Data Center; to present information on the solar landfill site suitability analysis; and to present an overview of the wind siting and analysis tool.	Activities Presentation on the Rhode Island Energy Data Center; presentation on assessing the feasibility of harvesting solar energy on Rhode Island landfills; presentation on the RESP wind energy siting tool; discussion of RESP online resources.
Stakeholder Meeting #7, March 1, 2011 (Attendance: ~40)	
Purpose of meeting To present an overview of the RESP Hydropower Working Group; to review the data & maps generated for the wind energy siting tool; to introduce RESP public comment process; to preview the upcoming RI Renewable Energy Day event, March 31st.	Activities Presentation on the findings of the RESP Hydropower Working Group; Presentation on the science used to develop the RESP approach to wind turbine siting; overview of the RESP Public Comment Process; discussion of RI Renewable Energy Day plans.

2.2 Field Trips

The RESP team conducted four field trips to existing renewable energy sites around Rhode Island during September and October, 2011. Field trips provided a first-hand view of existing renewable energy facilities in the state and allowed attendees to learn from experienced facility operators about the successes and challenges experienced with renewable energy in Rhode Island so far. Like stakeholder meetings, RESP field trips were open to all members of the public.

<u>Portsmouth Wind Turbine.</u> On September 22, 2011, about 35 members of the public toured the wind turbine at Portsmouth High School, a 336–foot (102.4-meter) turbine that has operated since early 2009. Gary Gump, chair of the Town of Portsmouth's Economic Development Committee Sustainable Energy Subcommittee, led the tour. Variable wind speeds that day enabled attendees to observe the turbine both at rest and in motion. Attendees experienced first-hand the smooth, rhythmic sound of the blades spinning, audible only at the base of the turbine. They also learned about the economics of this wind turbine, which provides electricity for Portsmouth High School and the Town of Portsmouth.

<u>Thundermist Hydroelectric, Woonsocket.</u> On October 13, 2011, about 30 stakeholders, students, and members of the public visited the Thundermist Hydroelectric facility, a 1.2MW hydropower facility located on the Woonsocket Falls Dam on the Blackstone River. The tour was led by Charlie Rosenfield of Putnam Hydropower, the company that owns the facility. The tour began with an exploration of the outside dam and water intake system, and then continued inside the plant to view the generator and dry transformer. Built as a flood control structure in the 1950's, the plant was converted to a hydroelectric generator in 1982 and ran until 1999. After a period of dormancy, Putnam Hydropower began operating the plant on behalf of the City of Woonsocket in 2009. The facility produces about 5000 MWh each year. This electricity is sold to National Grid at the clearing price for electricity. According to Rosenfield, establishing interconnection with the grid took about nine months and accounted for about 15% of the project's total costs. The plant's output is dependent on river flow, which means that during dry periods in the summer the plant must sometimes shut down its operations. During the winter and spring, however, the flow is usually adequate to supply the maximum capacity of 800 cubic feet per second. Over the course of a typical year, the plant operates at about 40% of its maximum capacity.

<u>New England Institute of Technology Wind Turbine.</u> On October 20, 2011, about 45 stakeholders and members of the public visited the New England Institute of Technology (NEIT) in Warwick to view a 156 ft (47.5 m) wind turbine that NEIT installed in 2009. Host Mike Eggeman explained that NEIT installed the turbine after performing a carbon footprint analysis of the school and deciding to ramp up the school's focus on green technologies. While students are not able to work on the turbine (Alteris Renewables takes care of maintenance), many are

assigned to monitor the turbine's movement and electricity generation rates as part of their curriculum. NEIT representatives explained that the blades of the turbine are black in order to absorb sunlight and inhibit ice formation, a concern stemming from the proximity of the turbine to Route 95. Representatives showed guests slides of the construction process, which they said took about two days and followed a yearlong pre-construction siting and analysis phase.

Toray Plastics Solar Park. On October 27, 2011, about 40 members of the public toured the solar field at Toray Plastics in the Quonset Business Park, North Kingstown. Shigeru Osada, Senior Vice President of Toray, led the tour. This company, which produces polyester and polypropylene films for the food packaging and industrial markets, relies on a very energy-intensive manufacturing process. In an attempt to curb energy expenses, in 2010 the company installed a 3.5 acre solar array, consisting of 1650 panels with a total nameplate capacity of 375 kW. Attendees observed first-hand the facility's automated, sun-tracking solar panels and learned about the economics of solar energy. Toray predicts that its solar energy facility will save the company between $70,000 and $80,000, and that the project will have a 5-10 year payoff time.

2.3 Municipal Working Group

Because of their key role in making renewable energy siting decisions, municipalities are expected to be the most immediate end users of RESP guidelines and tools. Recognizing the special informational needs of municipalities, the RESP convened a Municipal Working Group for six meetings between October 2011 and March 2012. Attendees included town planners, town managers, and town council members from all of Rhode Island's 39 cities and towns, as well as representatives from regional planning councils. Sessions, which took place at the University of Rhode Island Bay Campus, were open to the public but targeted towards the needs of municipal planners and decision makers.

Topics discussed at Municipal Working Group meetings generally paralleled discussions at RESP Stakeholder meetings, but gave municipal officials a direct opportunity to raise their most pressing questions within the context of a small, focused group setting. A list of meetings and topics is presented in Ch. 5 Table 3. The intimate setting of the Municipal Working Group also provided an arena to test RESP online decision support tools, making sure that the tools produced were user-friendly and informative, bearing in mind the particular needs of the municipal audience.

Ch. 5 Table 3. Municipal Working Group Meetings

Meeting Date	Topic
October 4, 2011	Discussion of current municipal experiences with renewable energy projects and proposals; discussion of informational needs.
November 17, 2011	Presentation on "The Structure of Renewable Energy Financing in Rhode Island"; open discussion.
December 8, 2011	Discussion of the experiences municipalities have had with renewable energy, in particular Jamestown, North Kingstown and Charlestown.
January 19, 2012	Review of RWU work on municipal renewable energy ordinances; discussion of draft model ordinance proposed for RI.
February 16, 2012	Discussion of a wind siting methodology tailored to the needs of RI municipalities.
March 15, 2012	Presentation on the RESP Wind Siting Constraint Analysis; Presentation on R.I.'s "Net Metering Law, Interconnection, and System Reliability
July 12, 2012	Presentation of the findings, online resources and siting tools developed for the RESP. The RESP team provided step by step instructions on how to use the wind energy siting toolbox, as well as the solar energy and hydropower viewers on RIEnergy.org.
August 30, 2012	Discussion of comments from Municipal Working Group members on RESP Documents/Products. There was also a discussion of whether this municipal forum should be continued following the completion of the RESP process. The creation and interest in municipal solar and wind ordinances was discussed including lessons learned, questions and challenged by cities and towns who have gone through the process.
October 18, 2012	Discussion with the Commissioner of Energy Resources for the Rhode Island Office of Energy Resources on challenges currently facing cities and town in the siting and review of renewable energy projects. Municipal officials were able to provide input on useful next steps fowling the completion of the RESP.

2.4 Wind Energy Siting Working Group

The Wind Energy Siting Working Group predated the RESP but was ultimately merged with RESP efforts. This group was formed in 2010 to help the Rhode Island Statewide Planning Program develop a set of wind energy siting guidelines that could be adopted and/or modified by

Rhode Island municipalities for their own purposes. The effort to develop these guidelines, grew out of the Statewide Planning Program's mandate to integrate renewable energy into Rhode Island's State Guide Plan. Due to significant overlap between the purposes of this project and the RESP, the RESP team worked hand in hand with the Statewide Planning Program to integrate technical expertise and community voices into the Guidelines. The Wind Energy Siting Working Group was key in this effort.

The Wind Energy Siting Working Group was made up primarily of municipalities and state agencies, but also included non-governmental organizations, developers, and independent citizens. During the first phase of Wind Energy Siting Working Group meetings, before its integration with the RESP, members consolidated scientific and technical guidance on wind energy siting from Rhode Island and other locations. During the second phase of the group's meetings, the group drew on this information and on the expertise presented in the RESP to develop a set of recommendations for standards and siting guidelines for wind energy in Rhode Island municipalities. These recommendations were included as Statewide Planning Program's "Renewable Energy Siting Guidelines Part 1: Interim Siting Factors for Terrestrial Wind Energy Systems" in Volume 3 of this RESP report. These wind siting guidelines were released for public comment with the draft RESP documents in the summer of 2012, however, they are currently undergoing further review by OER and SPP and will not be released with the final RESP document.

Ch. 5 Table 4. Wind Energy Siting Group

Member	Affiliation
Jeff Broadhead	Washington County Regional Planning Council
Lisa Bryer	Town of Jamestown
Julian Dash	RI Economic Development Corporation
Thomas Getz (Retired)	RI Department of Environmental Management
Daniel Goulet	Coastal Resources Management Council
Gary Gump	Town of Portsmouth
Amy Kullenberg	Conservation Law Foundation
Karina Lutz	People's Power and Light
Daniel Mendelsohn	Applied Science Associates
Colin O' Sullivan	North Kingstown Resident
Kenneth Payne (Retired)	RI Office of Energy Resources
Garry Plunkett	East Bay Wind Consortium
Jon Reiner	Town of North Kingstown
Andrew Shapiro	Apex Wind
Larry Taft	Audubon Society of Rhode Island
Barry Wenskowicz	Narragansett Bay Commission

2.5 Library Lecture Series

Between January and March 2012, the RESP hosted four hour-long informative lectures at libraries and community centers around Rhode Island. The purpose of the lecture series was to provide an entry-level avenue of involvement for people in communities throughout the state. Since these lectures demanded less intensive participation and travel time compared to stakeholder meetings, they served to bring in people who might not otherwise have become part of the RESP process.

<u>What's in the Wind? Meteorological Observations for Energy Siting</u> (North Kingstown Free Library; January 24, 2012). URI researchers John Merrill and Annette Grilli discussed the science of measuring the wind to identify the most productive sites for wind energy development in Rhode Island.

<u>Mapping Rhode Island Renewable Energy</u> (Westerly Public Library; February 6, 2012). URI researcher Chris Damon shared mapping tools developed by the Environmental Data Center at URI to assess solar, wind, and hydropower resources in Rhode Island.

<u>Science for Siting: Engineering for Locating Wind Turbines</u> (Rogers Free Library, Bristol; February 15, 2012). URI researchers Malcolm Spaulding and Gopu Potty gave an overview of land-based wind energy resources in Rhode Island and shared a strategy for siting wind energy facilities that considers wind resources, technological and development constraints, and ecological issues.

<u>Wind Power and Wildlife: Assessing Potential Impacts on Birds and Bats</u> (Kettle Pond Visitor Center, Charlestown; March 8, 2012). URI bird scientist Peter Paton shared the science of how flying animals respond to infrastructure such as wind turbines.

<u>Property Values</u> (URI Bay Campus; TBD) This event will be a facilitated discussion between stakeholders, real estate professionals (such as realtors, appraisers) and the leading expert in this field Ben Hoen, a Principal Research Associate in the Electricity Markets and Policy Group at the Lawrence Berkeley National Laboratory. Because this topic

2.6 Rhode Island Renewable Energy Day

On March 31, 2012, the RESP stakeholder process culminated in an all-day event at the Community College of Rhode Island Newport County Campus. The purpose of this event was to formally launch the final products of the RESP process and to reach out to stakeholders who had not yet been involved in the RESP process. The free public education event, co-hosted by the RESP team and the East Bay Energy Consortium (EBEC), was attended by about 100 people. The event featured opportunities for the public to contribute to the RESP's effort to develop community-based renewable energy siting and learn about local collaborations that foster public engagement with renewable energy development in the state.

The day began with speaking by U.S. Senator Sheldon Whitehouse and a representative of the Office of Rhode Island Governor Lincoln Chafee. This was followed by a presentation titled "What is the Renewable Energy Siting Partnership producing for RI?" and a panel discussion called "What is the future of renewable energy in Rhode Island?" In the afternoon, participants broke out into small groups. Two sets of concurrent sessions focused on the following topics:

- Hydropower Potential in Rhode Island
- Wind Energy System Siting Guidelines
- East Bay Energy Consortium (EBEC) – Wind Energy Project Update
- Landfill Solar Potential in Rhode Island
- Implementing RI's New Energy Legislation: How It Can Work for Municipalities
- Property Value Impacts – Facilitated Discussion

Like the RESP monthly general stakeholder meetings, Renewable Energy Day offered an opportunity for municipalities, energy developers, members of the general public, and others to come together and discuss concerns and opportunities relating to renewable energy development in Rhode Island. While the event's individual sessions focused on specific issues within this wider topic, the event took a big-picture view, engaging participants in an assessment of important knowledge gathered to-date through the RESP and a sharing of visions for future action supporting appropriate siting and permitting of renewable energy in Rhode Island.

2.7 Property Values Work Session

The RESP held a work session on Thursday, September 20, 2012 to discuss existing knowledge on the impacts of wind turbines on residential property values. The session took place from 6:00-8:00 p.m at the URI Coastal Institute Auditorium, and was attended by approximately 30 people (sign-in sheet available upon request). The following is a summary of the points discussed at the meeting, and highlights possible next steps recommended by stakeholder participants and researchers.

Current research evaluating wind turbine effects on property values

The first part of the workshop was led by Ben Hoen, Principal Research Associate from the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory. Mr. Hoen shared a PowerPoint presentation summarizing large-scale economic studies performed to date on the relationship between wind farms and property values. The presentation reviewed five recent studies of market transactions occurring in the vicinity of wind farms in various states around the U.S.[1]The largest of these studies, conducted by Mr. Hoen's lab in 2009, examined 7,500 property transactions in nine states. Variables measured in these studies included proximity to turbines, visibility of turbines, and sales prices. The studies controlled for other factors, such as trends in the housing market, which also affect home sales prices.

[1] These studies analyzed projects in Oregon, Washington, Texas, Oklahoma, Iowa, Illinois, Wisconsin, Pennsylvania, New Hampshire, and New York

Of the five major studies that Mr. Hoen reviewed for the group, none provided evidence to the hypothesis that wind turbines exert negative effects on nearby property values. Mr. Hoen pointed out, however, that some studies have detected a dip in property values coinciding with the *announcement* of a wind energy project. According to research cited by Mr. Hoen, this dip has been shown to reverse itself after the project has been installed, suggesting that turbines become an accepted part of the landscape and that any decline in property values occurring during the post-announcement, pre-operation phase is due to fear of the unknown. Thus, the overall conclusion suggested by these studies is that wind turbines tend not to be a significant factor in determining home sales price, although the apprehension felt prior to the installation of a proposed wind energy facility may temporary exert a negative influence on home prices.

In spite of the lack of evidence emerging from large-scale studies for a negative impact of wind turbines on property values, several stakeholder attendees at the workshop remained concerned about the potential for negative effects of this type to occur in Rhode Island. They questioned the local relevance of the large-scale studies summarized by Hoen, identifying two primary reasons for concern:

- All five studies reviewed by Mr. Hoen examined potential effects on property values resulting from *multi-turbine wind farms*, not single turbines. Due to a lack of large tracts of land available for large scale multi-turbine wind projects in Rhode Island, single turbine projects are expected to be the focus of future development proposals in Rhode Island municipalities. Thus, participants questioned whether the emerging understanding of the property values effects of wind farms would be applicable to a Rhode Island context.
- The five studies presented did not closely examine the effects of turbines on properties *within one mile* of wind energy facilities. Notably, those studies all took place in locations where population density is much lower than in Rhode Island. In Rhode Island, there are instances where homes are located as close as 400 ft from a wind turbine; therefore, effects in this close proximity are of particular concern in our state.

The 2009 study carried out by Mr. Hoen's lab is a demonstration of how the best available science regarding property values effects of wind turbines may be only partially applicable to situations typical in Rhode Island. Known to be one of the most comprehensive and widely cited analyses of the effects of wind turbines on property values, the 2009 study included only 125 sales (less than 2% of the total sample of 7,500 sales) within one mile of wind energy facilities. The shortest distance between a property and a turbine in the sample was 871 ft. Additionally, the smallest wind energy facility included in this study's sample consisted of seven turbines and produced 12MW of power. Rhode Island's largest existing wind energy facility, for comparison, produces 1.5MW. Responding to stakeholder concerns, Mr. Hoen agreed that the possible effects on property values exerted by wind turbines less than one mile away and the potential effects of facilities consisting of only one or a few turbines have not been thoroughly examined by researchers.

Stakeholder participants at the session made reference to several sources of information that support the need to fill these gaps. These include expert opinions voiced by homeowners, property appraisers, real estate agents, and others with personal experience relating to properties in the vicinity of wind energy facilities. Stakeholder participants brought up several instances in which these sources have attributed a change in property value or buyer behavior to the development of wind turbines in their local area.

Outcomes /Next Steps

Teresa Crean of the University of Rhode Island Coastal Resources Center and Rhode Island Sea Grant led the second part of the session. Ms. Crean asked participants to share ideas for future research in Rhode Island that would improve understanding and predictability of wind turbine impacts on property values in our state. Participants stressed the importance of conducting new kinds of analysis, while also tailoring analyses to a Rhode Island context. Responses included:

- Study the effects of wind energy facilities on properties at distances under one mile, including those in very close range (e.g., under 1,000 ft) to a turbine.
- Study the effects of single-turbine facilities (i.e., not wind farms) on property values.
- Conduct research on possible impacts of wind turbines on sales volume, not just sales values, of nearby properties.
- Examine relationships between the existence of wind turbines and the length of time that nearby properties are on the market.
- Look for changes in appraised property values, not just sales prices.

Two economists in attendance at the session, Dr. Corey Lang and Dr. Jim Opaluch from the University of Rhode Island Natural Resource Economics Department, announced that they have obtained a data set consisting of records of over 380,000 property sales in Rhode Island occurring between 1988 and 2011. Future findings based on analysis of this data set could have direct applicability for understanding the effects of recent turbine technology in a Rhode Island setting. Like many of the statistical studies performed to date in other parts of the country, this data set would enable comparison of average sales prices at varying distances from existing turbines, and comparison of sales prices in selected areas before and after turbine installation. In addition, this data set could be used to fill some of the data gaps identified by stakeholder participants and confirmed by Mr. Hoen at the session, including the effect of wind turbines on the value of properties in very close range to the turbines, and potential effects of single-turbine facilities, as opposed to wind farms. Moreover, the data could support research on effects occurring during the "in-between" period, after the announcement of a proposed turbine but before a turbine becomes operational. This would allow for testing of the hypothesis voiced by Mr. Hoen that adverse impacts to property values are most likely to occur during the planning and construction phases. Finally, this data set could also enable similar studies regarding other renewable energy projects, such as solar photovoltaic installations.

In conclusion, RESP stakeholders have identified the further study of potential effects of wind turbines on residential property values as a major priority for future RESP action. While this topic was not originally contemplated as a major focus of the RESP, it has emerged as a central point of concern among stakeholders. Dialogue between Mr. Hoen and participants at the workshop identified a general lack of analysis nationwide focusing on the impacts of single-turbine facilities of the type likely to occur in Rhode Island and on the potential for impacts to occur on properties within close range to turbines. Research on the potential property values impacts of existing wind turbines in Rhode Island appears to be feasible and may provide valuable insight regarding these lingering questions.

3. Stakeholder Feedback

Stakeholder input to the RESP process played an invaluable role in making the process thorough and impartial. Suggestions offered by stakeholder meeting attendees helped to identify research priorities and to inform the renewable energy siting guidelines developed by the RESP team. A partial list of stakeholder input and its outcomes is presented in Ch. 5 Table 5.

3.1 Phase I: Issue Identification and Assessment

Municipalities emerged as the key players during this initial stage. Some had prior experiences installing renewable energy or dealing with community responses to proposed or installed renewable energy installations, and they came into the process with concrete questions and observations about renewable energy in Rhode Island. The input of municipalities was critical to identifying important issues to be included in RESP research and guided the planning of Phase II stakeholder meetings.

Ch. 5 Table 5. Examples of Stakeholder Input Received During Phase I of the RESP Process.

Stakeholder Suggestion	RESP Response to Suggestion
The RESP should investigate the impacts of wind turbines on viewsheds and cultural and/or historical resources.	RESP staff reviewed aesthetic/visual and cultural/historic standards and guidelines from around the world, and explored mechanisms to address these issues in R.I. The results of this literature review are included in Sections 1.3.7 and 1.3.8 of the RESP report Volume 1. RESP staff also assessed the potential for cultural/historic impacts associated with hydropower; the results of this review are contained within Sections 3.2.1 of the RESP report Volume 1.
The RESP should consider potential health impacts of wind turbines.	RESP researchers reviewed potential health impacts related to both sound and shadow flicker produced by wind turbines. The results of this literature review are included in Sections 1.3.3 and 1.3.4 of the RESP report Volume 1.
The RESP should take into account the potential for natural disasters when siting renewable energy projects.	RESP staff reviewed the history of structural failure of wind turbines and icing from around the world. The results of this review are included in Section 1.3.1 of the RESP report Volume 1. In addition, the RESP team built a fall zone viewer into the RESP online siting tool. This tool enables the public to visualize the potential distances that a turbine fragment or ice mass may be thrown by inputting location, fragment size, and turbine size and speed.
The RESP should draw on lessons learned in parts of the world where renewable energy is already prevalent.	RESP researchers continued to draw on a learning connection established between URI and many European experts during the Ocean SAMP, and considered hosting a conference to exchange knowledge with out-of-state experts.
The RESP should consider long-range operations and maintenance requirements for renewable energy projects.	The RESP team highlighted these issues during four tours of existing renewable energy facilities in R.I., to NEIT's wind turbine, the town of Portsmouth's wind turbine, Toray Plastics' solar array, and the Thundermist Hydroelectric facility.
The RESP should evaluate issues surrounding interconnection with the grid, substations & existing power lines.	The RESP team communicated with National Grid to obtain information on interlinkage potential.
The RESP should consider other opportunities for generating renewable energy, such as methane gas from landfills and sites for solar energy at places other than landfills.	The RESP framework was limited to wind energy, solar energy at landfills, and low-head hydroelectric, but the RESP team made note of these stakeholder suggestions as a possible basis for future research.

3.1 Phase II: Information Synthesis and Communication

During this stage, individual members of the public emerged as the most active participants. Their personal experiences and concerns lent trust and credibility to the RESP process and filled in some of the gaps that RESP scientific research was not geared to answering. For example, when a literature review of economic studies failed to turn up statistical evidence showing impacts of renewable energy on property values, stakeholders pushed the RESP coordinating team to look into anecdotal accounts of personal experiences with property values issues.

In another example, two Portsmouth residents were invited to present a video and verbal testimony describing some negative impacts of the Portsmouth municipal wind turbine on their daily lives. The residents' emotive descriptions of shadow flicker and noise impacts brought to life the potentially dramatic consequences that wind turbines can have on nearby residences. While not all residents are likely to be affected in the same way, this testimony opened attendees' eyes to the importance of appropriate siting and community consultation in wind energy development. Thanks to this and other stakeholder input provided during this phase, the RESP was able to complement scientific findings with human voices in their analysis of renewable energy impacts.

In addition to complementing the scientific research performed for the RESP, the stakeholder process played a role in steering this research. For example, the economic analysis performed for the RESP was initially intended to be more of a high-level academic exercise, but when members of the public requested development of a widely accessible, back-of-the-envelope tool that anyone could take advantage of, RESP researchers shifted gears to accommodate this request.

3.2 Phase III: Develop Final Products

Final products were developed that synthesized the scientific findings, as well as the concerns of stakeholders. In addition, web-based tools were created to allow municipalities and the public to apply the findings of the RESP.

3.4 Phase IV: Public Comment and Review

In total approximately 315 comments were received during the public comment phase. The final RESP documents and web components were revised as a result of input received during the 60-day public comment period and all comments received on Volumes I, II and RIEnergy.org were responded to by the RESP team explaining what changes were made to the final products as a result of the suggestion, or an explanation of why the suggested change was not accepted. Comment responses are available online at the project website http://seagrant.gso.uri.edu/resp. Comments received on Volume III, "Renewable Energy Siting Guidelines, Part 1: Interim Siting Factors for Terrestrial Wind Energy Systems" are also available on the project website. They were also provided to OER and SPP for consideration as the wind siting guidelines are reexamined.