Renewable Energy Sources Evaluation

Beverly, Massachusetts

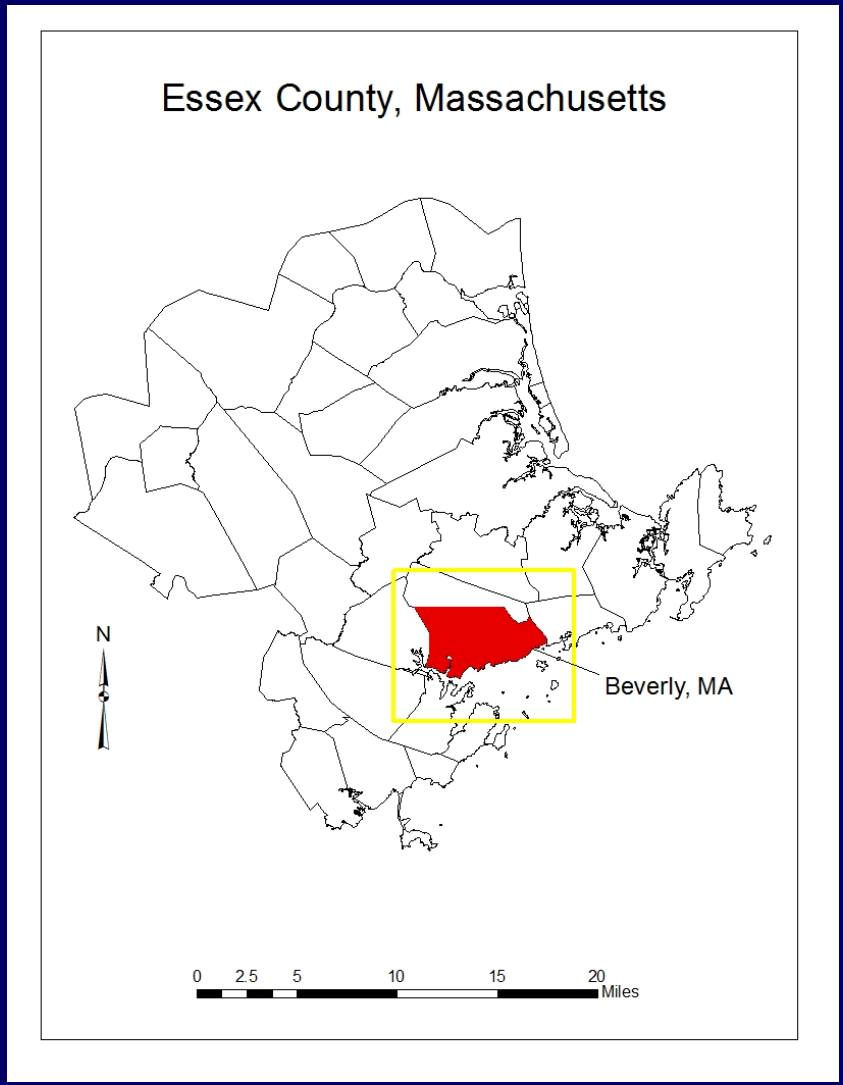
Matt Tormey

Research Objective

- Explore and evaluate the potential for renewable energy sources in a New England community
- Evaluate two of three renewable sources: biomass, wind, solar
- Community Selected: Beverly, Massachusetts
- Follow an evaluation that was done in Poultney, Vermont and published in Renewable Energy Journal
- This article was used as an outline for renewable sources in Beverly

Location

- Northeast Region of Massachusetts
- Essex County
- Coastal City
- Borders Manchester, Wenham, Danvers, and Salem
- Established 1626



Demographics

- Total Population = 39,862 People
- Median Age = 38.3 Years Old
- 96% White
- Household Population = 37,692 Residents
- Housing Units = 16,275
- Actual Homes = 7,764

- 9 Schools
- 3 Fire Stations
- City Hall / Police Station
- 2 Libraries

Source: US Census 2000

Energy Usage

Massachusetts

- Total Electricity Consumption = 54 Trillion kWh in 2009
- Population = 6,547,629
- Electricity Consumption Per Capita = 8,302 kWh
- Cost per kWh = 14.27 cents, 4.65 cents higher than National average

Beverly

- Total Electricity Consumption = 330 Million kWh in 2009
- Population = 39,862
- Electricity Consumption Per Capita = 8,302 kWh
- Cost = $47,224,328

Sources : EIA and US Census 2000 & 2010

Major Industries and Land Uses

- Primarily Residential
- Some Commercial
- Some Industrial
- Cummings Center
- Downtown Areas Mix of Residential and Commercial
- Parks and Playgrounds
- Few Ponds and Streams
- Coastal Beaches

Cummings Center,

Solar Now Inc.

- President Jimmy Carter Administration
- Authorized the construction of 8 experimental solar research facilities
- Dr. John W. Coleman Greenergy Park, located next to Beverly High School
- One of the largest of the 8 facilities and the only one still active
- Has been providing power to Beverly High School for 30 years
- Small wind turbine was installed to complement the solar panels
- Currently run by Solar Now Inc.

Source: www.solarnow.org

Solar Now Inc.

Pictures Taken By Matt Tormey 5/1/11

Cabot Street Apartment Building

Picture Take By Matt Tormey 5/1/11

Data Needed for Analysis

Shapefiles

- Town Polygons
- Essex County Land Use
- 50 Meter Wind Speed Classification
- Parcel Polygons
- Protected Space Polygons
- Wetland Polygons
- 2000 Census Block Data Layer

Other

- Digital Elevation Model (DEM) 1/3 ARC
- Orthographic Photos 15 cm Resolution

Methodology For All Renewables

- Download All Data from Internet Sources (Mass GIS, USGS)
- Re-project All Data to Massachusetts State Plane Mainland Coordinate System if needed
- Cut Away Excess Data Outside of Beverly
- This streamlines the rest of the process by minimizing the data and reducing potential errors

Biomass Fuel In Beverly

Criteria

- Ruled out Agriculture
- Slopes Must be $\leq$ 20%
- Classified as Forest
- No Bodies of Water or Wetlands
- No Protected Space
- No Open Space
- No Conservation Land
- Parcel Size Over 2 Hectares
- Final Polygon Size Over 2 Hectares
- 1 ha = 70 odt, 1 odt = 15 million Btu, 3412 Btu = 1 kWh

Methodology

- Isolate Land Classified as Forest from the Land Use Shapefile
- Eliminate All Slopes > 20%
- Exclude All Protected/ Open/ Conservation Land
- Exclude All Bodies of Water and Wetlands
- Eliminate All Parcels < 2 Hectares
- Eliminate All Remaining Polygons < 2 Hectares
- Calculated Acreage, Biomass Yields and Energy Content

Biomass Tables

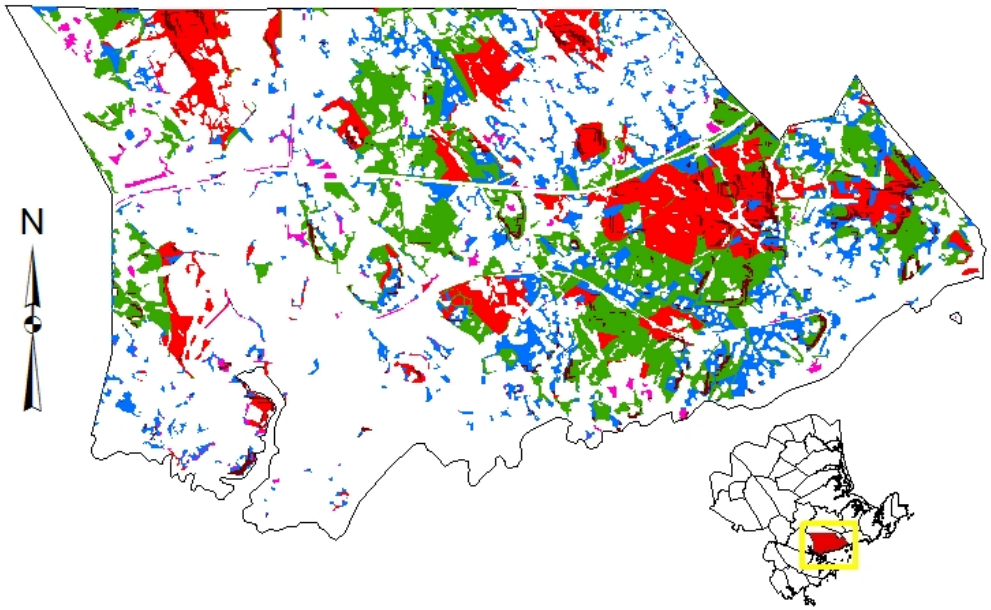
Forest Acreage

Criteria	Total
Total Forest Land	1390 ha
Slope > 20%	87 ha
Open Space Excluded	375 ha
Parcel Size < 2 ha	353 ha
Polygons < 2 ha	39 ha
Total Excluded	854 ha
Remaining Forest Land	536 ha

Forest Estimate of Biomass Yields (odt)			
	Low (0.1%)	Medium (0.5%)	High (1.0%)
Average (70 odt/ha/year)	37.50	187.50	375.00

Forest Estimate of Energy Content (Btu)			
	Low (0.1%)	Medium (0.5%)	High (1.0%)
Average (70 odt/ha/year)	562,500,000	2,812,500,000	5,625,000,000

Forest Land
Beverly, Masschusetts



Available Areas

- All Forest Land
- Available After Slope < 20 Excluded
- Available After Slope < 20 & Protected/Cons. Land Excluded
- Available After Slope < 20, Protected/Cons. Land, & Parcels < 2 ha Excluded
- Final Available Forest Land

* All Colors Represent Forest Classification

0 0.45 0.9 1.8 2.7 3.6 Miles

Wind Energy In Beverly

Criteria

- Slopes $\leq 60^{o}$
- Wind Classification ≥ 2
- No Bodies of Water
- No Wetlands
- No Protected Space
- No Open Space
- No Conservation Land
- Turbine Height of 50 Meters
- Average Tree Height Roughly 30 meters
  - Three most common trees in Beverly
    - Eastern White Pine (80'-100')
    - Red Maple (60'-90')
    - Eastern Hemlock (100')

Methodology

- Isolate Wind Classifications ≥ 2
- Eliminate All Slopes $> 60^{o}$
- Exclude Wetlands
- Exclude Protected/ Open/ Conservation Land
- Select 3 points from the remaining locations
- Viewshed Analysis Performed with Turbine Heights of 50 meters
- Used DEM
- Layered resulting viewshed on top of 2000 Census Blocks
- Calculated Population Affected and Area

Source: Massachusetts Land Owners Association

Wind Tables

Area Figures in Beverly, MA

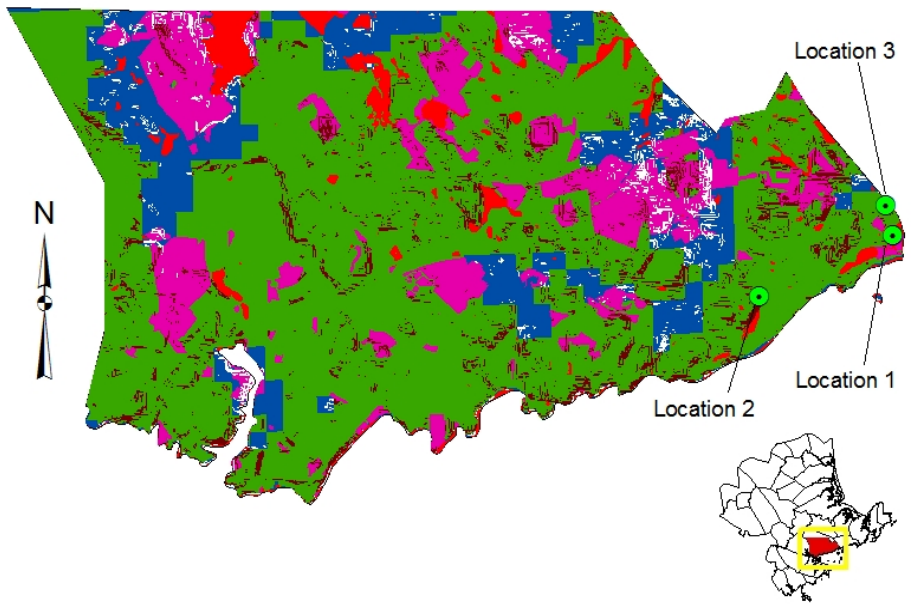
Criteria	Total
Total Area	4,006 ha
Slope ≥ 60 Excluded	342 ha
Protected Space Excluded	543 ha
Wetlands Excluded	164 ha
Wind Class < 2 Excluded	511 ha
Total Excluded	1,560 ha
Total Available Lands	2,446 ha

Wind Turbine Site 1	
Approx. Location	Block # 2,004
Number of Blocks Affected	154 out of 605
Total Viewshed Area	403 ha
Total Population Affected	2,478 Residents

Wind Turbine Site 2	
Approx. Location	Block # 9,001
Number of Blocks Affected	245 out of 605
Total Viewshed Area	651 ha
Total Population Affected	6,147 Residents

Wind Turbine Site 3	
Approx. Location	Block # 5,014
Number of Blocks Affected	142 out of 605
Total Viewshed Area	409 ha
Total Population Affected	2,271 Residents

All Possible Wind Turbine Locations
Beverly, Masschusetts

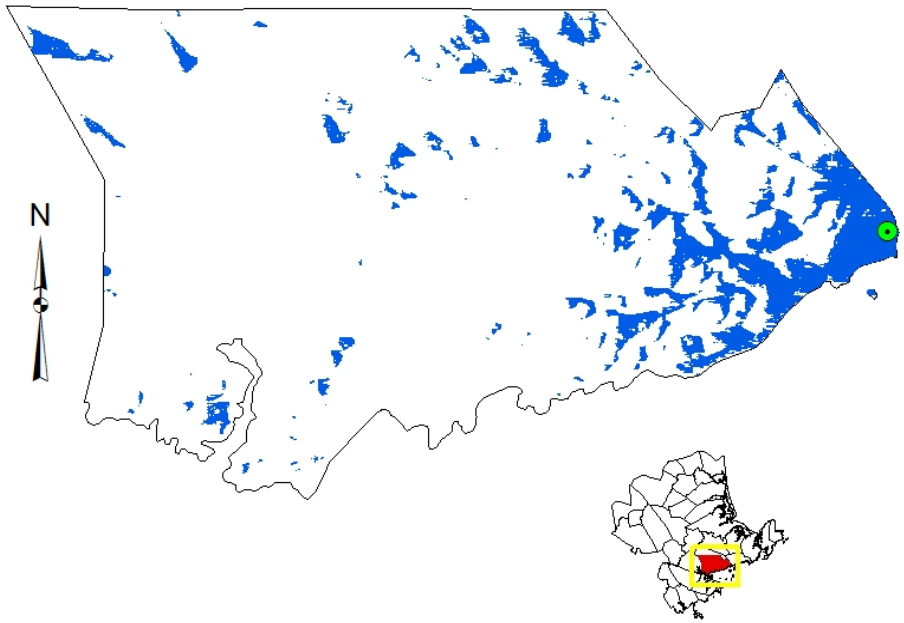


Available Areas

- Available After Wind Speed < 2 Excluded
- Available After Wind Speed < 2 & Slope < 60 Excluded
- Available After Wind Speed < 2, Slope < 60 & Protected Excluded
- Available After Wind Speed < 2, Slope < 60, Protected, & Wetlands Excluded
- All Possible Locations

0 0.5 1 2 3 4 Miles

View Shed of Site Location 1
Beverly, Masschusetts

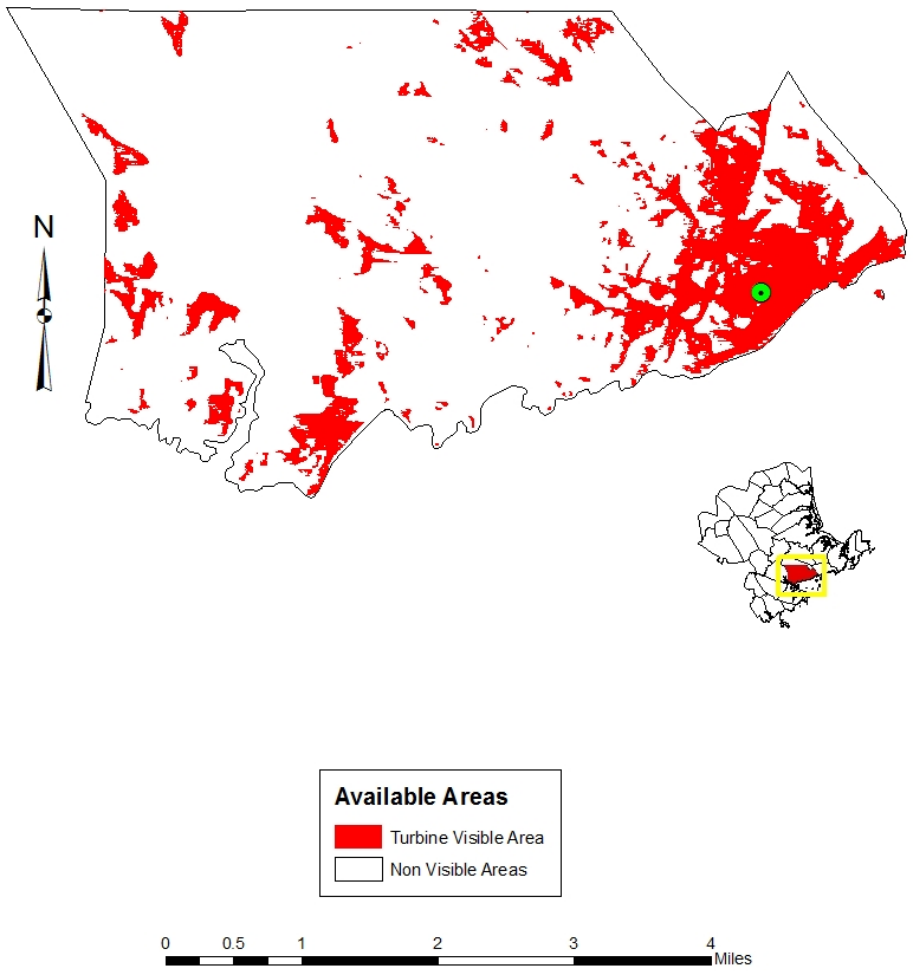


Available Areas

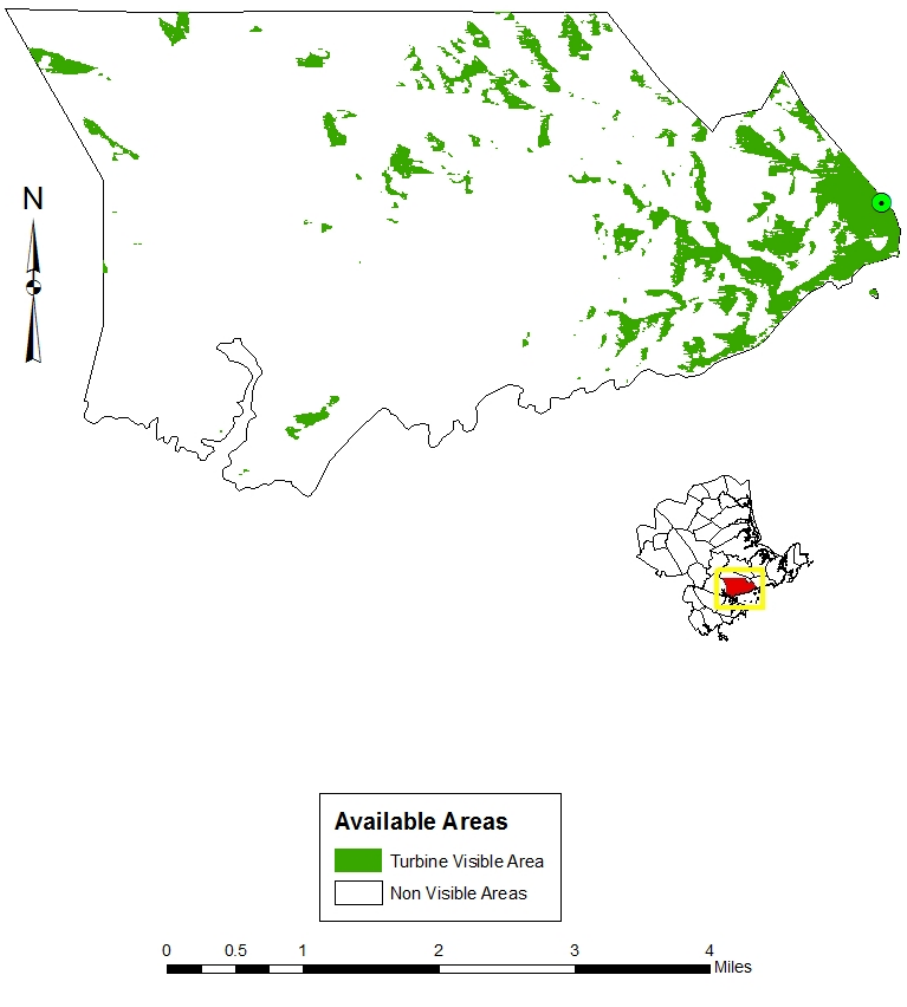
- Turbine Visible Areas
- Non Visible Areas

0 0.5 1 2 3 4 Miles

View Shed of Site Location 2
Beverly, Masschusetts



View Shed of Site Location 3
Beverly, Masschusetts



Solar Radiation In Beverly

Criteria

- Buildings Owned by the City of Beverly
- 9 Schools
- 3 Fire Stations
- 2 Libraries
- City Hall / Police Station
- Radiation for 2011
- 50% Rooftop Availability
- 16% Efficiency
- 90% Transmission Rate

Methodology

- Calculate Solar Radiation for year 2011 using DEM
- Digitize Selected Buildings and created new vector file using Ortho Photos
- Calculate Rooftop Area
- Perform Zonal Statistics using the radiation and Digitized Buildings
- Combine Tables and Perform Calculations

Solar Table

Radiation Figures for Beverly Massachusetts Public Buildings (Schools, Fire Departments, Libraries, City Hall)						
Building Name	Total Rooftop Area (m^2)	Available Rooftop Area 50% (m^2)	Zonal Radiation ($WH/m^2/yr$)	Radiation on Building ($KwH/m^2/yr$)	Energy Captured By Panels 16% ($KwH/m^2/yr$)	Energy After 90% Transmission Rate ($KwH/m^2/yr$)
City Hall/Police Station	864	432	1,202,419	519,445	83,111	74,800
Ayers Elementary School	6,180	3,090	1,200,685	3,710,116	593,619	534,257
Beverly High School	20,771	10,386	1,201,701	12,480,267	1,996,843	1,797,158
Briscoe Middle School	5,565	2,783	1,204,906	3,352,651	536,424	482,782
Centerville Elementary School	5,725	2,863	1,191,552	3,410,818	545,731	491,158
Cove Elementary School	6,357	3,179	1,205,520	3,831,746	613,079	551,771
Farms Library	462	231	1,210,979	279,736	44,758	40,282
Fire Department (Central Station)	486	243	1,215,573	295,384	47,261	42,535
Fire Department (Farms Station)	335	168	1,211,846	202,984	32,477	29,230
Fire Department (North Beverly)	288	144	1,210,730	174,345	27,895	25,106
Hannah Elementary School	6,722	3,361	1,205,993	4,053,344	648,535	583,682
Library	1,460	730	1,206,191	880,519	140,883	126,795
McKeown Elementary School	2,884	1,442	1,203,291	1,735,145	277,623	249,861
Memorial Middle School	4,971	2,486	1,206,883	2,999,709	479,953	431,958
North Beverly Elementary School	5,835	2,918	1,199,308	3,498,982	559,837	503,853
Totals:	**68,905**	**34,453**	**18,077,578**	**41,425,192**	**6,628,031**	**5,965,228**

Centerville School Digitized Sample

Results

- Potential for 1,666,178 kWh to be produced from biomass burning yearly
- Potential for 5,965,228 kWh to be produced from rooftop solar panels yearly
- Accounts for roughly 2% of Beverly's electricity consumption
- A higher percent can be achieved by installing wind turbines in the eastern most part of Beverly
- Only 15 buildings were selected for solar panels which means more electricity can be produced with more buildings
- If the solar panels only power their own buildings, residents still benefit because they are paid for by tax payers
- Overall benefit by reducing electricity produced by Salem Power Plant

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Questions?