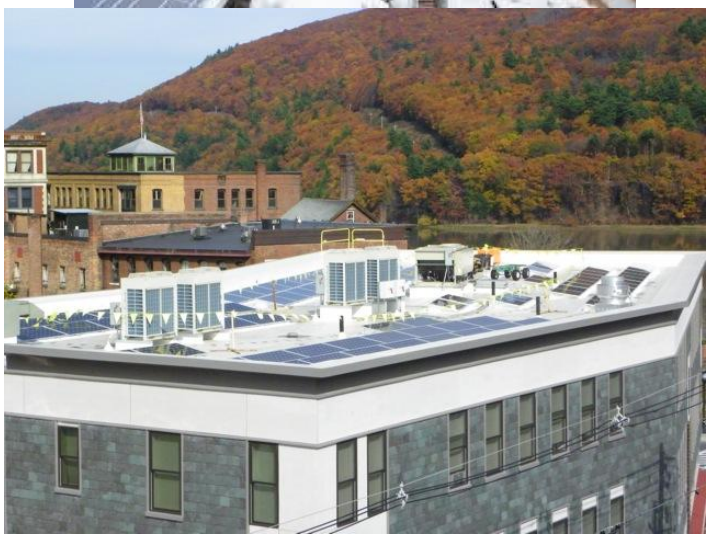
Can Cheshire County Reach 100% Energy Generation from Renewable Resources?



Logan Felix

Environmental Studies/ Occupational Health Safety Major

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1. Introduction

Although I have spent a very short time of my life here in New Hampshire, I have developed a love for Cheshire county. Whether it be hiking Mount Monadnock, or going shopping in downtown Keene, there is much to offer here. A strong presence of local involvement coupled with a sense of community in the area is a very valuable characteristic! Part of the reason for doing this project is that I hope to see a clean, green, and sustainable future for this area. I enjoy winter sports, however these activities such as this are at risk with a warming climate. The science is there, and this theory is beginning to look more like a reality more and more in the last few years. Action needs to happen as quickly as possible. The time is now, our citizens, legislatures, and mother earth can no longer wait.

The theory of Climate change, often referred to as “global warming”, is an existential threat to life on earth as we know it. A variety of different species, and ecosystems are at risk of being lost due to this phenomenon. Although others may thrive, diversity of different plants in animals will drastically decrease. This is due to increase in droughts, phenomenon like coral bleaching from rise in Co2 in oceans, and coastal sea level rise (Science.org). Climate change deniers often argue that, “the climate is always changing”, and therefore this is nothing to be concerned about. Yes, the climate is in fact changing, and always has been for millions of years. The problem is that human activity is negatively affecting the change, by accelerating us into a period of warming. Carbon dioxide released from fossil fuels is the largest concern. Climate scientists warn that a 1.5-degree Celsius warming is dangerous. According to the Intergovernmental Panel on Climate Change (IPCC) (IPCC, Global Warming of 1.5 degrees), we have already reached a 1-degree

Celsius increase from pre-industrial temperatures. If we reach a 2-degree increase, this will have significant environmental effects. Some issues that will arise include, habitat loss, extreme droughts, events of intense rainfall, and more severe storms and other weather events. The Global Warming of 1.5 degrees report mentions effects pertaining to those not just living on the coast. Those living in inland New Hampshire, such as Cheshire county may ignore the realization of climate change, thinking it will not affect them due to most of the state being inland, and at higher elevation. The Intergovernmental Panel on Climate Change (IPCC), states that, "climate-related health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5 degrees Celsius and rise further with a 2-degree increase" (summary for policymakers, IPCC).

Many Individuals have advocated for renewable energy and lowering of emissions to be a top priority in this country. One of the leaders in bringing this issue to the attention of the masses was a man by the name of Al Gore. Gore's film, *An Inconvenient Truth* talked of the dangers of climate change. Another large step in the efforts was during the Obama administration. President Barack Obama had created what is known as the "Clean Power Plan". First proposed by the EPA in June of 2014, the plan was an attempt to reduce carbon dioxide emissions from electrical power generation by 32 percent by 2030, relative to 2005 levels (Peter Foster, 2018). Several cities and towns across the country have also begun to switch their energy sources to one that is renewable. Some have even gone as far as becoming entirely run on these resources. Sadly, our current administration, led by President Donald J. Trump has put this energy transition progress on hold. Kicking of his

term, President Trump decided to back out of global agreement to cut emissions known as "The Paris Climate Agreement". This action was a major roadblock in the global effort to mitigate climate change. Although this was a major blow to the environmental movement, we have not given up. Climate change has in recent years been getting much more media coverage. More and more people are begining to become aware of this, which is a vital step to activism as well as social change. Regulations pertaining to air quality control, as well as pollution are routinely enforced and have dramatically improved in the last few decades. The United States undeniably has some ground to cover if we want to be at par with the environmental policies of European and Scandinavian countries. Places like Sweden are boasting that 53% of its county is powered by renewables (Frangoul, 2017). This is great news in the global efforts in combating climate change and leaving a more sustainable future for generations to come. The United States has some work cut out for them if they plan on reaching 100% renewable energy generation.

1.1 Research Question and justifications

The research question is:

Can Cheshire county meet its energy demands with the use of renewable energy sources? Is it feasible to use sources such as wind, solar, and hydro power, to heat and cool its homes, run manufacturing facilities and business, and provide the area with electricity, as well as power an all-electric car system?

Background/Context

Why we should do this….

Despite this being a formidable goal, it is vital that we achieve it for the following reasons. One major reason would be the large number of negative effects to the area. There are many ways in which inland New Hampshire will be affected directly, and indirectly by a rise in average global temperatures related to climate change. One may think that due to the fact that the Southwestern region of the state is far from the coast, that we will not be affected by these extreme weather changes. This is not the case. Cheshire county will face direct and indirect effects due to the changing climate.

Indirect effects may be the most threatening to people living in the area. According to the Intergovernmental Panel on Climate Change (IPCC), "Increasing warming amplifies the exposure of small islands, low-lying coastal areas and deltas to the risks associated with sea level rise for many human and ecological systems, including increased saltwater intrusion, flooding and damage to infrastructure. (Global Warming of 1.5 ℃, b.2.3)." If this were to occur, there will be hundreds of thousands of U.S citizens that will become climate refugees. These displaced people will be looking for new places to live that are further inland. New Hampshire is primarily rural, with plenty lots of developable land for sale. Although this new migration of citizens may be good for the economy, this new development will destroy the wilderness

appeal of the state. As new houses go up, the States expansive forests will begin to disappear. Not only would this affect tourism, many of the plant, and animal species in the area will be at risk.

Some direct effects we will face are more weather related. With our current trend of emissions, scientists predict more extreme weather. We have already begun to see more intense hurricanes in states like Florida, and North Carolina in late 2018. Hurricane Michael was the largest storm to hit the Florida Pan Handle and it will take years to recover from the damages (CNN,2018). With more frequent and intense storms, Cheshire county can expect significant amounts of rain and snowfall. For the entire Northern Hemisphere, there is evidence of an increase in both storm frequency and intensity during the cold season since 1950 (U.S Global Change Research Program, 2015)**.** If this is the case not only will insurance rates rise due to the increase in damages associated with these storms, serious injury and even death from these events could occur. If we do not act quickly these negative effects will occur, and our traditional way of life hear in the Live Free Or die state will drastically be changed.

Moral argument

Second, there is a moral argument to make: The United states is currently second to china for largest release of yearly emissions (Union of Concerned Scientists, 2018), we ought to be one of the first countries to reduce them. Sadly, this is not the case. With our current policies in place, and current administration, we need to take matters into our own hands. President Trump has expressed his belief that climate change is a hoax and is working on reopening a number of coal fired power plants around the country. This viewpoint directly

contrasts the latest climate assessment report released by his own administration, warning of the dangers of climate change. With that being said we as citizens need to start addressing the issues ourselves. Our first priority should be energy efficiency. If we can reduce our consumption, then we would simply not have as high of a demand. This can be achieved with a combination of behavioral, technological, and governmental changes. A behavioral change may consist of things such as turning off the lights when you don't need them or lowering the temperature on the thermostat during the winter months. Approaching the issue from a technological standpoint would require actions like, switching that light bulb to one that is more energy efficient, or investing in an electric heat pump. Both of these approaches can be achieved by the homeowner, as well as from the commercial and industrial sector. One of the most important ways to mitigate this issue is by government oversight and regulation. Unfortunately, not all Americans will accept this change right away, and will need incentives to do so. Whether it be from lowering electric rates for those who switch to renewables, or things like ride sharing programs, and carbon taxes for large power plants. By voting for those who support the idea of climate change, and believe in a renewable energy future, we can be one step closer to a more sustainable and stable environmental future.

Third, the local economy will benefit from this new development. Cheshire county has essentially achieved no job growth since the great recession in 2008 (New Hampshire Fiscal Policy Institute, 2018) The unemployment rate in Cheshire county as of August 2018 stands at 2.7% (FRED, 2018). The local economy will see major benefits to these projects. Installing solar systems whether it be residential rooftop solar, or a commercial operation, from production to instillation everyone gets a piece of the pie. From the production of the panels themselves, to

the company who sells them, and the installer who makes it all happen, economic growth is occurring. With this influx in new jobs, the area could also see a growth in population, as people would move to the area for work. With new renters, tax payers, and shoppers, Cheshire county will undoubtedly receive economic growth.

Public Health Benefits

Public health is another major issue associated with "dirty industry", that can be curved with the aid of renewable energy. "Each year in the United States alone, pollution from coal power plants is responsible for more than 13,000 premature deaths and 20,000 heart attacks, and hundreds of thousands of asthma attacks (Clean Air Task Force, 2010)." Coal power plants are not the contributor to health-related issues caused by fossil fuels. Natural gas, as well as combustion of gasoline (Co2) in the transportation sector, leads to respiratory issues. As these projects are installed, and our reliance on natural gas, oil, coal, and wood. This is especially beneficial to Keene, Cheshire's largest city. The city is located in a valley and frequently experiences air inversions. This becomes a major issue in the colder months, due to an increase in wood smoke for heating of resident's homes. These weather events lead to an increase in exposure of particulate matter, or PM2.5. If we can convert all of the heating in the area to all electric heat pumps. These are the most efficient forms of heat and if run by renewables will produce no pollution. Another concern in the region, especially in the Keene area is automobile emissions that affect air quality. Due to large amounts of commuters entering the valley, poor air quality results from the influx of traditional combustion engine automobiles. If we were to convert all, or even a large percentage of vehicles to electric, this issue can also be avoided.

The energy picture in USA and NH

As our demand for energy increases, we are becoming more and more reliant on new, and cheaper ways to power our homes, businesses, and manufacturing facilities. During the years of the industrial revolution, the United States relied heavily on coal for its development. As we became more and more aware of the negative effects of coal on public health, and the environment, an energy transition began to occur. Nuclear power then began to take over coal as our major source of energy. Although it was a very efficient form, there was questions to its safety following the meltdown of 3-mile Island in New York, as well as the disaster that had recently taken place in Japan. As plants across the country began to close, we needed another contender to feed the grid. Renewables such as wind, solar and hydro, began to gain popularity. European countries had already pushed heavily for this clean source of energy and had been very successful in its application. However, due to the price of renewables, and the push back by large oil companies, a new source known as natural gas took the cake as the largest contributor of energy production in the nation (Eia.gov,2018). Although cleaner than coal, and in some cases viewed as a "Clean Energy", the extraction process, of these gasses, as well as its refining process have been proven to be very detrimental to those living near the extraction cites.

Other places are doing it already, USA, Germany, etc.

We can clearly have some ground to cover with "renewable" energy investments. In the last decade or so, the industry has been taking massive leaps towards weening ourselves off of fossil fuels. There has been several cities and towns across New England that have taken the 100% pledge for sustainability. At the start of 2015, Burlington Vermont became the first city to

be completely powered by renewables. Thirty percent of Burlington's energy is generated by a biomass plant, plus 50 percent from hydro generators and an additional 20 percent from wind turbines and solar panels (PBS,2015)**.** This means that the city is producing more than it uses and is providing its 40,000 residents with clean renewable energy. Several towns in the live free or die state have also pledged their commitment to 100% renewable electricity generation by the year 2030, this includes Concord, and Cornish (Sierra Club, 2018). Although the state has a lot of ground to cover in the path towards full sustainability, local government has been taking serious action. State policies can help speed up the transition. For example, in the neighboring state of Massachusetts it is still easier to install a solar array on your home. This is due to programs like

The city of Keene, which has the largest population in the county, clearly makes up most of the energy use for the area. According to the 2015 greenhouse gas emissions inventory, the commercial and industrial emissions for the city of Keene are primarily due to electricity consumption, 62% to be exact (City of Keene 2015, p.16). This makes it very clear of the benefits that could be gained from switching to renewable energy. If we can switch our electricity sources to renewable the majority of carbon emissions in the area will be lowered. Another major contributor of greenhouse gas emission in Cheshire is from the transportation sector. Unfortunately switching over to an all-electric vehicle system will take a large amount of time and finances. No communities in the country have been able to include 100% sustainable transportation in their reports. This had proven to be one of the larger challenges during the energy transition. While six cities in the United States alone have been able to receive all of their electricity from renewable sources, citizens are still driving gas powered vehicles. With the

aid of state or local carpooling incentives, increase in public transportation, and lowering the costs of electric vehicles, over time this may be possible.

Literature review

a. Defining renewable energy

Terms like “renewable energy”, “clean energy”, “Green energy”, are often tossed around. People often believe that these words are interchangeable. However, this is not the case. Renewable energy refers to an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind (Science Daily, n.d). This source of energy will never expire as long as the sun continues to shine, and the wind continues to blow. It is by far the cleanest form or energy we currently can obtain. “Clean energy” is a term used by different stakeholders in different ways. There is a lot of grey area in the actual definition of this term. Some define it as including sources such as natural gas, and nuclear power. Others have the term include “clean coal, or carbon capturing technologies.” A website affiliated with the sharing of information on electric vehicles, solar and wind power, would clearly have a more stringent definition of the term. Cleantechnica.com defines “clean energy” as not including sources like natural gas, clean coal, or nuclear power. Despite them being bias, it is becoming increasingly clear that these forms of energy are being marked as “clean”, in order to increase their appeal and acceptance among the general public. This is by far the case with the concept of “clean coal”.

b. Gains in electrification

When you do this with electric motors and compressors, you save a tremendous amount of Btus (energy). Petroleum powered cars and other vehicles lose a significant amount of potential energy when burned. If the traditional gas-powered car were to be switched with an electric car, it would be 5 times more efficient **(Calculated Data)**.

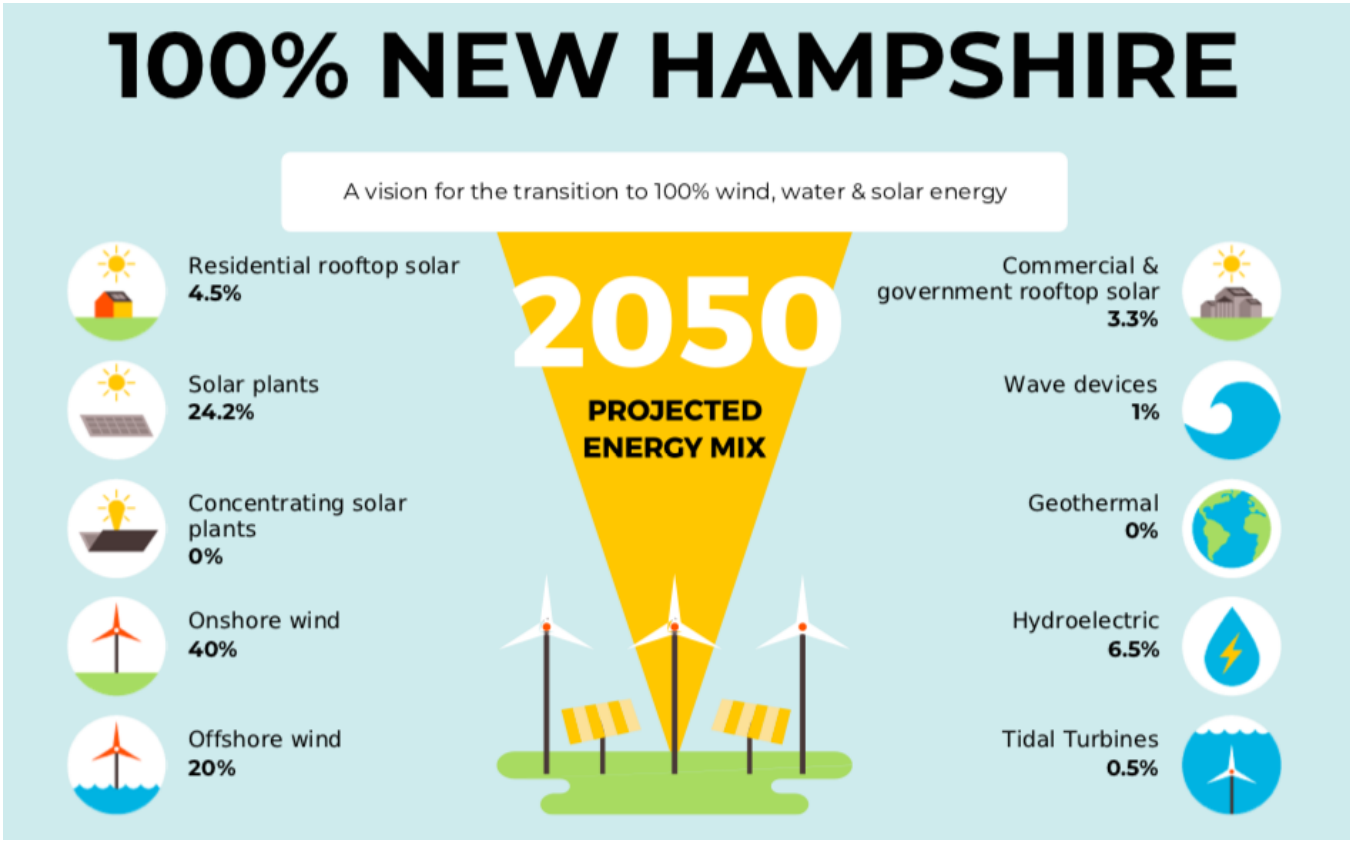
c. Mark Jacobson and his case for a 100% RE society

Mark Jacobson of Stanford University has been investigating the feasibility of meeting state, national, and world energy demand with renewable energy from wind, water, and solar (WWS) (Jacobson and Delucci 2011). He excludes CCS and nuclear energy from consideration because he claims these are not sustainable and because they are associated with dangerous environmental and public health threats. Jacobson's plan has gained a lot of public attention. In an interview with Stanford the scientist said that, "The main barriers are social, political and getting industries to change. One way to overcome the barriers is to inform people about what is possible..." This is what I hope to achieve after this project. My hope is to inform the public of the potentials of renewable energy, and perhaps persuade others to demand the change we so desperately need.

Jacobson's team has produced all-sector energy roadmaps for the 50 States, taking a deeper look in how we can make something like this a reality. His plan considers only WWS technologies as necessary sources. These include residential and commercial solar, on- and offshore wind, and hydropower. The plans divide the 100% renewable by percentages of a variety of different renewable sources. They also calculate the impact on jobs and on monthly energy cost savings. In order to come up with the percentages for each plan, a number of

calculations were done by Jacobson and his team. They started by determining the energy demand for each state. Next, data relating to the current amount and source of the fuel consumed was gathered and analyzed, then demand was replaced with electricity. This assumed that all cars would become electric and that homes and industry would be converted to fully electrified heating and cooling systems (Stanford University Communications,2015**).** The next portion of the plan would consist of how this new electric grid would be powered.

"Figure 1 shows what Jacobson's solution for New Hampshire would look like. Both on and offshore wind will supply 40% and 20% of total energy, respectfully. Commercial solar will meet about 25% of demand. Rooftop solar will be less than 5% of demand."



Jacobson's Vision for New Hampshire

Figure 1.

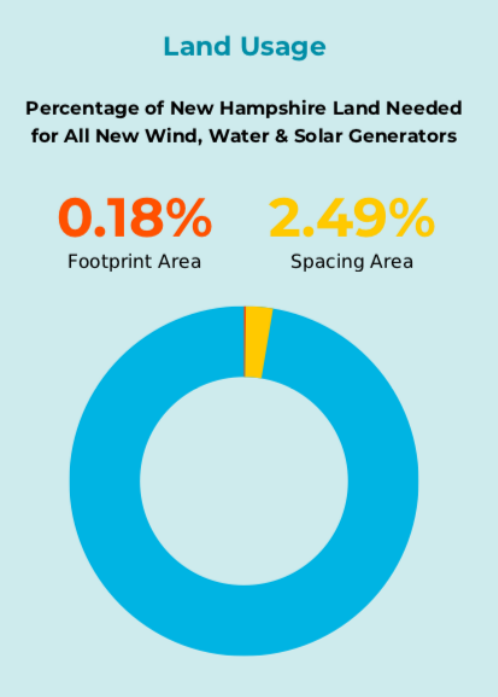


Figure 2

http://thesolutionsproject.org/why-clean-energy/#/map/states/location/NH

Solutions project

"The Solutions Project" is an organization working on spreading the message that it is not only possible for the United States to receive its energy from 100% renewables, but that it is already happening. The idea is that, "Through storytelling, grantmaking, and capacity building, we honor clean energy leaders, invest in promising solutions, and build relationships between unlikely allies (The Solutions Project, 2018)."

The “Solution” consists of 50 plans for 50 states, for 100% renewables generation by the year 2050. Using a similar approach to what I am doing, those involved in the study are extrapolating state data, to determine the demand of energy, and the future demand of whereby. They then determine the amount of energy from a variety of different renewable sources that would be necessary to meet this demand. According to the research the entire state of New Hampshire to reach 100% sustainability there needs to be a combination of several types of renewable energy sources. The report also includes economic benefits, and job creation related to this effort. Only 4.5% of demand would be met with residential rooftop solar. The potential for rooftop solar in 2012 for the state was 13.9 km2 for residential homes, and 9.3km2 for commercial and governmental buildings (*Energy Environ. Sci.,* 2015, 8, 2093).

Due to the fact that trees may need to be cleared in order to build wind turbines or solar farms, these methods may not be the best choice of renewables. However, if this technology is installed either on a preexisting structure such as atop a roof, or build off shore this issue of deforestation, is avoided.

Methodology

(Here you just say that you answered two research questions: (1) what demand is, (2) how it can be met)). Then have a sub-heading for each of these research questions:

Estimating demand of an all-electric Cheshire county

To estimate the electric energy needed to meet all energy demands of Cheshire County, I analyzed each end-use sector separately. I drew upon data from the Energy Information Agency (EIA) when possible, but also used input from ISO-NE, the NH Sustainable Energy

Association, the Northern New England Real estate network, and by estimating demand, a number of assumptions had to be made. I chose to be conservative in my assumptions, erring on the side of over-estimating rather than underestimating. The demand estimated in these reports is clearly an overestimate. The data collected was both percentages and averages for the state. Most is available to the public and is updated annually.

Residential sector

This sector includes all energy directly used by households for space heating and cooling, appliances, and water heating. (Transportation is handled under a separate sector.) Eversource would not release private data without the customer's consent. Eversource also does not have user data bundled by end use sector or political geography. Consequently, it was impossible to get direct measures of past electric energy consumption for the region.

Fortunately, EIA data was available for the residential sector for the State of New Hampshire as a whole. EIA reports that in 2016, the residential sector statewide consumed 4,438 million kWh (USEIA, 2018:327). These data refer to the existing residential demand, for which I assume an insignificant portion is due to electric vehicle charging, due to the small number of electric vehicles registered in the state.

Because this project will assume that all space heating and cooling as well as water heating needs in a 100% RE future will be met with high-efficiency heat pumps, the portion of the existing electric energy demand that is used for electric resistance (ER) heating and cooling (hot water and heat) must be subtracted from this 4,438 MWh. This will leave us with only the electric energy demand for appliances and light.

To estimate the portion of the existing electric energy load used for ER space heating and cooling, I first found out the number of homes in NH that rely on electric baseboard heat. I then multiplied it by the average energy use for a single unit in an average sized home, about 2000 sq ft.

To calculate the present-day ER hot heater demand, I estimated the percentage of households in Cheshire county that have an ER hot water heater. After speaking with a plumber in the area, I found that around 60% of homes currently use ER hot water heaters. I then calculated the average consumption of an ER hot water heater using a formula from the US department of energy (US DOE, 2018) and Bradford White (Bradford White n.d.). After subtracting out the demand for the electric resistance space heating and hot water, I estimated the demand for heat pumps. For hot water I used the same DOE website as stated above, substituting 3.24 for the efficiency rating. For space heating, I used the energy cost calculator available by the Department of Energy.

Commercial sector

The US EIA has data on the commercial sector by state (US EIA 2018:328). I took New Hampshire state data and extrapolated it down to the county level based on Cheshire county's population. The EIA data break down energy consumption by fuel. I assume that present day electricity consumption if for light and pumps and this will not change. However, all fossil fuel and wood consumption are for space heating and will need to be converted to electric heat pumps. It is possible that some of the propane is used to power forklifts and other equipment, but there is no way of no I assume it is used for heating. I assume the 1.344 tBtu of fossil fuels is

used to make heat, and I calculated how many GWh would be needed to drive heat pumps to produce that amount of heat energy.

Industrial sector

The same US EIA data are available for the industrial sector. Once again, I extrapolated to the county level based on population. This could be conservative; however, it is difficult to estimate. Table 4 lists the largest employers in the county, and very few are industrial operations. Once again as in the commercial sector I assumed that all the fossil fuels are used to produce heat and can be achieved using electric heat pumps.

Transportation sector

One again I used the data available in the US EIA 2018 report. It lists the total consumption of transport related fuels in the state. I focused only on gasoline and diesel fuel, ignoring jet fuel, propane, and other lubricants because they were not significant amounts.

For diesel trucks, I took the total number of gallons of diesel fuel sold and multiplied it by the average fuel efficiency of an 18-wheeler Mack truck to calculate total number of miles driven. I then found that new electric trucks consume an average of 2 KWh per mile. From this I was able to calculate the total electricity demand for the state and was then able to extrapolate it to the demand necessary for the county. I followed this same formula for gasoline.

Estimating present day renewable energy production in Cheshire county

I asked local experts about the presence of wind, water, and solar generation, and found that there is no wind turbine generation in the county. I also did not include geothermal or biomass in the production.

Solar

I gathered information on current registered rooftop solar in the county from information provided to me by Karen Kramden of the New Hampshire public utilities commission's sustainability division.

See Appendix for list of Solar locations

I used a capacity factor of 0.2 for solar in New Hampshire to calculate the total energy produced from these facilities.

System power (MW) * Capacity Factor * hours per year = energy generated (MWh)

Hydropower

How will you do this?

1. What data is available from the EIA
2. State energy consumption
3. Data available from Southwest regional planning commission

4. Data from Granite state hydropower association
5. Data from Public Utilities commission

Calculations of energy consumption in Cheshire county

Transportation

1. Other modes of transport (rail, air): will be excluded because they are not substantial
2. Power needed to meet transportation demand
3. Calculations for electric car vs gas car

Electricity needed to meet transportation demand
NH used **86.3 tBu** for motor vehicle gasoline in 2016

I then converted tBtu to gallons
114,000 Btu/gal
This gave me **757 million Gallons**

I then found the average mpg for a gasoline car **(26.4 mpg)**

Then using this I found the average miles traveled per year in the state (**19985 million miles)**

Electric vehicles get an average of **4.0 miles per kWh**

Using this number, I was able to come up with **4996 million kWh** were necessary for the entire state, 5% of the state is Cheshire County, therefore

Roughly **280 GWh** are needed to power an all-electric car system

Electric cars are 5 times more efficient

b. Calculations for converting diesel power vehicles to electric

Same methods as listed above

Residential

Electricity demand for appliances

Calculations

State	4438 GWh	EIA p. 327
County	249 GWh	
Electric Resistance hot water	102 GWh	
Electric Resistance heat	82 GWh	
Net	65 GWh	Appliances and light
Total	487	100% RE electricity demand

60% of hot water heaters are electric according to Adrian Pinney Plumbing and heating

Estimated energy demand for all households

Hot water

Hot water = 0.60 * 35631 (population of Cheshire County) * 400 kWh =

21,378*4 mWh=
85,514 mWh This is the current demand for electric hot water heaters in the county.

35,631 housing units in Cheshire
634,666 Population of New Hampshire
Cheshire is 5.6% of the state

0.056 * 4438 kWh= 250 kwh
Energy used in the county for residential sector

Commercial energy demand

Light	4241 tBtu
Gas heat	2248 tBtu
Other Heat	500 tBtu
total	6989 tBtu

EIA 2012 report on commercial consumption

EIA NH report for commercial

	State	County
Electricity	15.2 tBtu	0.8512
Gas	8.8	0.4928
Oil	13.5	0.756
Wood	1.7	0.0952
Total Heat	**24**	1.344 (this can be reduced using heat pumps)

Electricity	**4466**	250 (Assume this cannot be reduced)

EFF	101 kWh/MMBtu	14.71$ per MMBtu	
Load (NH)	1.344 tBtu	0.145 $ per kWh	
	1344000 MMBtu	101 $ per kWh	
Heat only	136 GWh		
Light	250.096 GWh		
Total	386 GWh		

Industrial Energy Demand

	State	County
Electricity	6.8 tBtu	0.3808 tBtu
Gas	8.7 tBtu	0.4872 tBtu
Oil	7.5 tBtu	0.42 tBtu
Wood	4 tBtu	0.224 tBtu
Total Heat	20.2 tBtu	1.1312 tBtu (assume we can reduce this by using heat pumps)
Electricity	2000 tBtu	112 tBtu (assume this cannot be reduced)

Field Setting description

Cheshire county has a very traditional old new England town feel. With an average year-round temperature of 46 degrees F, the area experiences mild summers, and cold winters, with plenty of rain and snow. With the city of Keene in a valley at its center, and plenty of wilderness areas, it really is a great place to be. Cheshire is the 6th largest county in the state at only around 75,000 people. The area is largely rural, making it an ideal location for renewables, and has plenty of room for development. Despite not having much potential for geothermal energy, there are plenty of renewable potential geographically. Although there is not as much elevated terrain, as say the white mountains region of the state, the area does receive a fair amount of wind. However, the city of Keene itself is located in a valley that does not receive very much wind. There are currently no large-scale wind operations in the county. Hydro power companies have taken advantage of the Ashuelot river which flows through the area. Currently there are three large scale hydro operations that are taking advantage of this. These operations are all owned by a company known as Ashuelot River Hydro. There is much more potential for hydro power in the area. Despite not much geothermal potential, the amount of area available for solar wind, and hydropower is very substantial.

Map of Cheshire County

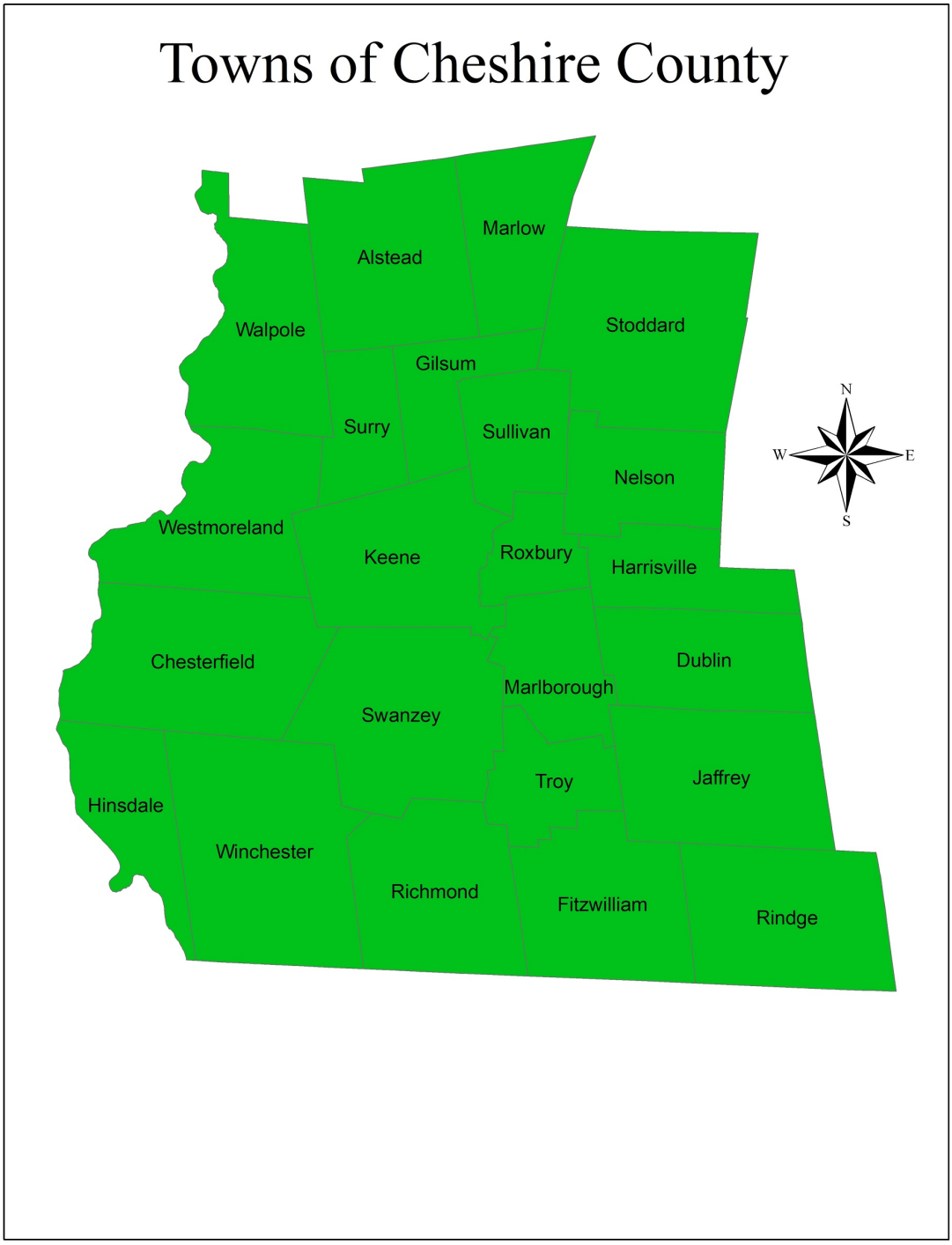


Figure 3.

List of commercial business

Largest Businesses	Community	Product/Service	Employees
Cheshire Medical Center/Dartmouth Hitchcock Clinic-Keene	Keene	Health care services	1,650
C & S Wholesale Grocers	Keene	Wholesale foods	1,200
Keene School District	Keene	Education	1,141
Keene State College	Keene	Education	916
Millpore Corporation	Jaffrey	Industrial filters	772
Monadnock Regional School District	Swanzey	Education	746
Imaje Corporation	Keene	Industrial marking equipment	400
Smith Industrial Medical Systems	Keene	Hospital supplies	380
Market Basket	Swanzey	Supermarket	355
Liberty Mutual/Peerless Insurance Company	Keene	Insurance services	354
National Grange Mutual Insurance	Keene	Insurance services	347
TFX Medical, Inc.	Jaffrey	Medical tubing	307
United Natural Foods	Chesterfield	Food warehouse	300
Franklin Pierce University (Rindge campus)	Rindge	Education	300
Market Basket	Rindge	Supermarket	275
TimKen Super Precision	Keene	Mini & precision bearings	258
Jaffrey-Ringe School District	Jaffrey	Education	256
Plum Pak	Winchester	Packaging, manufacturing	240
Wal-Mart	Hinsdale	Retail store	230
Wal-Mart	Rindge	Retail store	200
Maplewood Nursing Home	Westmoreland	Nursing Home	200
Town of Swanzey	Swanzey	Municipal services	171
Fenton Family Dealerships	Swanzey	Automobile dealership	164
Bensonwood & Unity Homes	Walpole	Manufacturer of wood framed & energy efficient homes	120
Hannaford Brothers	Rindge	Supermarket	114
W.S. Badger Co., Inc.	Gilsum	Hand lotion, balm	100
Mountain Industries	Marlborough	Silk screen products	100
HCP Packaging USA Inc.	Hinsdale	Design, development, and manufacture of packaging containers	100
Walpole Savings Bank	Walpole	Banking services	93
Good Shepherd Nursing Home	Jaffrey	Elder care services	91

Note: *All employer information, including number of employees, was provided by the individual communities.*

Figure 4.

Results

Consumption by sector

Transportation (Personal Vehicles/Diesel)

806 GWh

Residential

1. Currently consuming 250 GWh electricity
2. But this includes some electric resistance (ER) space heating (6% of homes) and ER water heating (60% of homes). We need to subtract these, since those are wasteful technologies that will need to be replaced with heat pumps
3. Estimated demand for ER hot water = 102 GWh (60% homes)
4. Estimated demand for ER space heat = 82 GWh (6% homes)
5. **Current demand (without ER hot water or space heating) = 65 GWh**
6. New demand for all heat pump hot water = 48 GWh (100% homes)
7. New demand for all heat pump heating = 374 GWh (100% homes)
8. **Total future demand = 487 GWh (an increase of +96%)**

Commercial

1. Currently consuming 250 GWh electricity
2. Assume this include no space heating or resistance water heating – all space heating is gas or oil
3. Est. demand for heat pump space heat/cool = 136 GWh

4. Total demand = 386 GWh (an increase of 55%)

Industrial

1. Currently consuming 112 GWh electricity
2. Assume this include no space heating or resistance water heating – all space heating is gas or oil
3. Estimated demand for heat pump space heat/cool = 227 GWh
4. Total demand = 338 GWh (an increase of 103%)

Current Renewable Energy Production

1. Wind

   No generation

2. Hydro

   Three hydro plants

   Lower Robertson= 0.84 MW

   Ashuelot River= 0.87 MW

   Minnewawa= 1 MW

   Total Hydro Energy= 11.87 GWh

3. Solar

   Residential

   1436 MWh

   Municipal

1139 MWh

Commercial

3504 MWh

Total Solar energy= 6.114 GWh

Total Renewable energy production= 20,989 MWh= **21 GWh**

Land Necessary for 100%

Assume 325 MWh per Acre (NREL Land use requirements for solar power plants)

Number of acres needed= 5,864 acres

Percent of Cheshire County= **1.26%**

See figure 5. Below

Land necessary to achieve 100% energy Independence

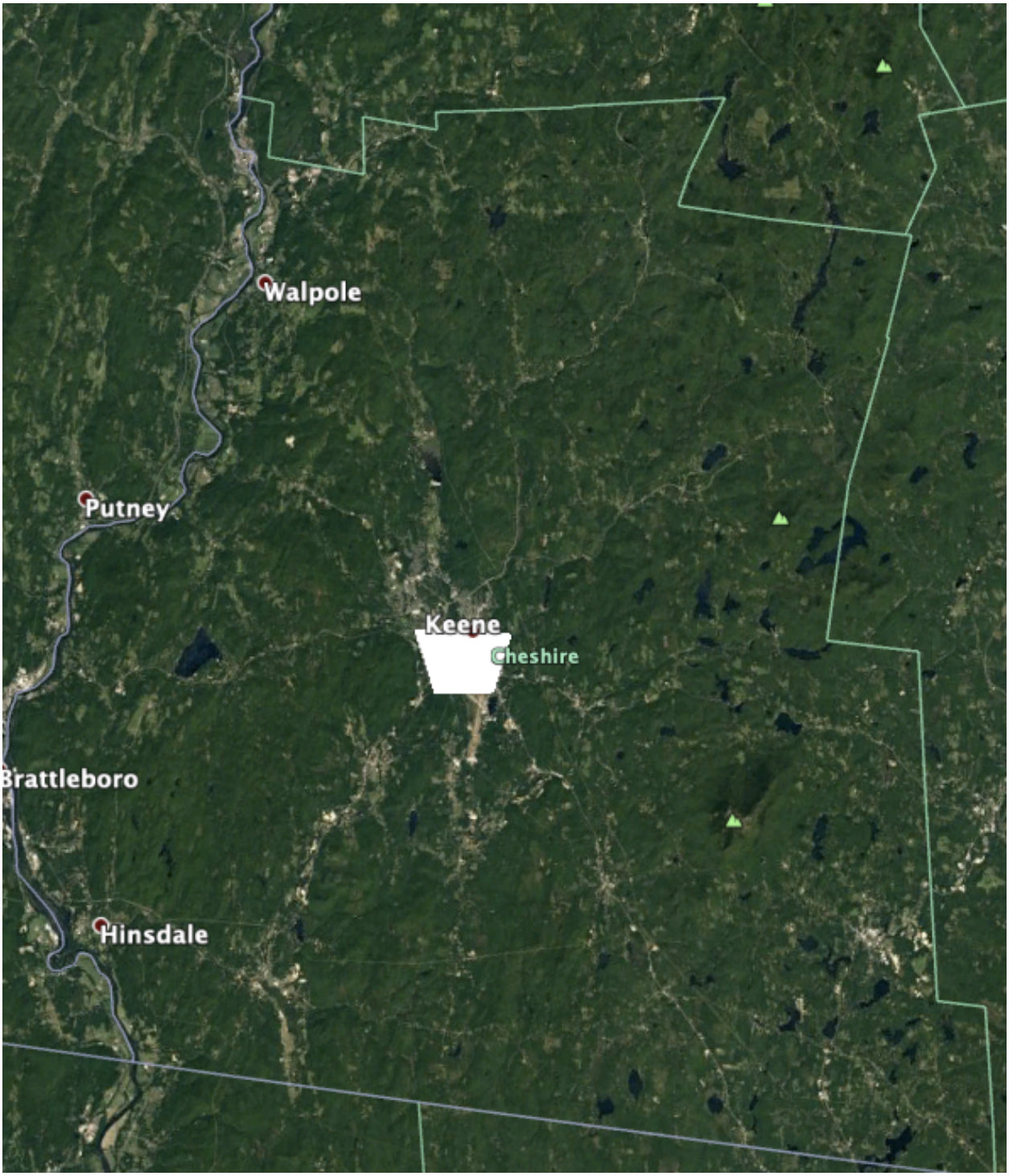


Figure 5.

Discussion

I am very pleased with the results that I have found for this project. Due to only a relatively small portion of land is needed for an all-electric system, these findings are a major persuading argument as to why we should switch to an all-electric system. Yes, there will be jobs lost from the traditional energy sectors, however the benefits from this transition largely outweigh these social costs. After discovering what is technologically feasible for Cheshire county, I am convinced that Jacobson's claims are entirely possible. Despite this area of the state not using a significant amount of energy when compared to the rest of New Hampshire, I excluded several other forms of renewables such as offshore wind, geothermal, as well as biomass fuels. Taking that into consideration is remarkable how much land we would actually need to dedicate to power such a large amount of residential, industrial, and commercial businesses. The fact that an achievement such as this is possible with our current renewable energy technology is truly remarkable.

Conclusion

In conclusion, I believe that the findings in this report are very beneficial in the vision of this country's sustainable future. As stated in Mark Jacobson's reports, receiving 100% of a state's energy from renewable is possible for every state in the country. An entirely electric grid

is feasible, this includes transportation. In my findings I have found that only a small portion of land in the county is necessary to achieve 100% energy independence. About 1.26% of the land in the county is necessary for electrifying the entire energy system. I am also a strong advocate for offshore wind. Cape wind was on track to be the United States first large-scale offshore wind operation. However, it was never approved. Deepwater wind located off the coast of block island as of 2016 has become the first offshore wind project in the United States. It consists of five turbines, generates about 30 megawatts of electricity (Deepwater Wind,2018). Although Cheshire County will not be able to build any offshore wind project, the area could benefit from their construction. The potential for energy generation along the northeast coast cannot be ignored. This technology is advancing rapidly and projects such as this one need to be executed.

This information will be provided to the southwest regional planning committee, as well as other local governmental offices and perhaps it will be of use to them in the efforts to execute a project of this magnitude. The upfront costs of a project this size is very large, however the profits will inevitably outweigh this. Although from a social standpoint a project of this magnitude will be difficult to predict, I hope to go more in depth on this in another project. I hope to learn more of the sociological aspects of achieving this goal, and what obstacles may occur along the way.

Appendix

REC Cert. #	Facility Name	City	System Size (mW)	REC Eligibility Date	Aggregator ID
Solar Generation	Commercial				
	RE/MAX Town & Country	Keene	0.00825	10/28/15	Eversource (PSNH)
	Furlone, LLC	Swanzey	0.0081	7/19/12	Eversource
	American Documentaries, Inc	Walpole	0.0081	11/5/15	Liberty
	Furlone, LLC	Swanzey	0.0656	9/11/15	PSNH
	Truck Camper Warehouse	Chesterfield	0.0656	3/13/12	PSNH
	Stone Pond Woodworking	Marlborough	0.06384	6/18/14	PSNH
	furlone, LLC	Swanzey	0.0615	6/10/16	PSNH
	Cypress Community Solar LLC	Keene	0.06	5/25/16	Eversource
	Beaman Logging	Winchester	0.00637	11/12/14	PSNH
	Five Wings Studio	Fitzwilliam	0.0063	6/3/16	Eversource
	TGF Tree-Free, Inc Tree Free Greetings	Keene	0.02106	2/1/16	Eversource
	Shippee Auto	Hinsdale	0.01968	6/8/15	Eversource

	Lake Homes NH, LLC	Fitzwilliam	0.01375	7/31/14	PSNH
	Steve Holmes Photography	Keene	0.01222	12/19/13	PSNH
RREC 18-0426	Target #T2120	Keene	0.364	4/12/18	
RREC 17-90013	Dublin Solar	Dublin	0.324	2017-01-26	
RREC 17-90104	Chamberlain Machine	Walpole	0.0999	2017-09-02	Knollwood Energy
16-1116	Yankee Publishing	Dublin	0.0684	2016-11-14	Knollwood Energy
16-555	MacDowell Colony I	Dublin	0.066	2016-05-09	
RREC 17-0315	Sunridge Farm LLC	Rindge	0.0657	2017-05-19	Knollwood Energy
16-529	Tree Farm	Keene	0.06	2016-05-02	Knollwood Energy
16-0930	Second Chance Solar, LLC	Keene	0.0456	2016-09-14	
RREC 17-90028	Monadnock Community Market Cooperative, Inc.	Keene	0.0324	2017-06-14	Revolution Energy Aggregation
RREC 17-0018	Savings Bank of Walpole	Keene	0.00545	2017-03-02	Knollwood Energy
RREC 17-0332	Heart Line Stove Shop	Jaffrey	0.0228	2017-05-31	Knollwood Energy
16-0803	Chesterfield Garage	Chesterfield	0.01764	2016-08-16	Knollwood Energy
16-1129	BP Keene, LLC	Keene	0.0167	2016-12-02	Knollwood Energy

16-1152	Yongro, Inc.	Winchester	0.0152	2016-11-29	Knollwood Energy
RREC 17-90022	Westmill Senior Housing	Keene	0.0144	2017-05-15	Revolution Energy Aggregation

Commercial Solar total (MW)

19.63305

16-591	Joan Galloway	Walpole	0.025	2016-05-23	Knollwood Energy
RREC 17-0400	George B. Foote, Jr.	Dublin	0.0219	2017-07-10	Knollwood Energy
RREC 17-0948	Bob Switzer and BJ Wahl	Sullivan	0.005	2017-12-21	Knollwood Energy
REC 15-100	Ernest Vose	Walpole	0.005	2015-03-23	Knollwood Energy
REC 15-127	Fred Dill Jr.	Walpole	0.005	2015-04-27	Knollwood Energy
16-800	Harold Bigelow	Winchester	0.005	2016-07-28	Knollwood Energy
REC 15-128	Jeff Kennedy	Alstead	0.005	2015-04-27	Knollwood Energy

16-1123	Jerome Galloway	Walpole	0.005	2016-10-07	Knollwood Energy
16-746	Johannes Van Riel	Marlow	0.005	2016-07-12	NHEC
16-1170	Randall S Walter	Westmoreland	0.005	2016-12-02	Knollwood Energy
RREC 17-0331	Charles Falcone	Stoddard	0.0045	2017-05-19	Knollwood Energy
16-429	Kyra Lewis	Jaffrey	0.0043	2016-04-11	Knollwood Energy
16-567	Pilar Abaurrea	Keene	0.00415	2016-05-13	Knollwood Energy
RREC 17-0475	William Hooper	Keene	0.00377	2017-09-11	Knollwood Energy
16-723	Derrell Hooper	Winchester	0.0036	2016-07-01	Knollwood Energy
DE 14-018	Filtrine Manufacturing	Keene	0.0036	2014-01-23	Revolution Energy Aggregation
REC 15-174	Paul Vasilak	Richmond	0.003	2015-05-26	Knollwood Energy
16-1198	Tom Doyle	Stoddard	0.0027	2016-10-24	Knollwood Energy
16-721	Susan Silverman	Fitzwilliam	0.0054	2016-07-01	Knollwood Energy
RREC 17-0091	Daryl Schillemat	Nelson	0.00525	2017-01-30	Knollwood Energy
RREC 18-0465	Lucius Evans	Chesterfield	0.01272	2018-05-14	Knollwood

					Energy
16-406	Bruce Beach	Chesterfield	0.0125	2016-04-07	
RREC 17-0798	Jason Ferland	Sullivan	0.012	2017-11-08	Knollwood Energy
16-1089	Dave Dumont	Chesterfield	0.01095	2016-10-12	Knollwood Energy
RREC 17-0497	Elwood Streeter	Surry	0.01095	2017-09-29	Knollwood Energy
RREC 17-0370	Hans Porschitz	Keene	0.01095	2017-03-12	Knollwood Energy
16-502	Aquilla Gorton	Walpole	0.01	2016-04-27	Knollwood Energy
RREC 17-0634	David and Jeanne Moody	Alstead	0.01	2017-10-24	Knollwood Energy
RREC 18-0494	Jason and Dawn Kovarik	Stoddard	0.01	2018-06-04	Knollwood Energy
REC 15-153	John Snowden	Westmoreland	0.01	2015-05-15	Knollwood Energy
REC 15-277	Peter Lawlor	Walpole	0.01	2015-07-09	Knollwood Energy
REC 15-278	Steve Grenier	Walpole	0.01	2015-07-09	Knollwood Energy
RREC 17-90039	Chris Ricci	Walpole	0.009995	2016-11-21	Knollwood Energy
16-670	Tracy Moore	Walpole	0.009995	2016-06-17	Knollwood Energy
16-0876	Douglas Palmer	Walpole	0.0099	2016-08-12	Knollwood Energy
RREC 18-0340	Michele Chalice	Keene	0.0098	2018-03-15	Knollwood Energy
RREC 17-90102	Richard Blair	Jaffrey	0.00928	2017-07-11	Knollwood Energy

16-570	Walter Ayers	Swanzey	0.009	2016-05-13	Knollwood Energy
RREC 17-0837	Ronald Pastor	Fitzwilliam	0.00878	2017-11-16	Knollwood Energy
RREC 17-90076	Barry Rhodes	Jaffrey	0.00835	2017-06-09	Knollwood Energy
RREC 17-0471	David Beers	Sullivan	0.00835	2017-09-01	Knollwood Energy
16-1224	Gustave Ruth	Winchester	0.00835	2016-12-13	Knollwood Energy
16-0915	James Wallace	Winchester	0.00835	2016-09-20	Knollwood Energy
RREC 17-0338	Mark Whippie	Keene	0.00835	2017-06-16	Knollwood Energy
RREC 17-0740	Michael Kasschau	Gilsum	0.00835	2017-11-05	Knollwood Energy
RREC 17-0214	Michael Keating	Marlborough	0.00835	2017-05-15	Knollwood Energy
RREC 17-0213	Peter Malloy	Westmoreland	0.00835	2017-05-15	Knollwood Energy
RREC 17-0578	Robert Lindberg	Swanzey	0.00835	2017-09-29	Knollwood Energy
RREC 18-0259	Tedd Benson	Alstead	0.00835	2018-02-26	Knollwood Energy
REC 15-123	Daniel Lewis	Alstead	0.008	2015-04-01	Knollwood Energy
RREC 17-0217	Daniel Sutton	Fitzwilliam	0.0077	2017-05-15	Knollwood Energy
REC 15-276	William Kingsbury	Walpole	0.0077	2015-07-09	Knollwood Energy
RREC 17-0942	David Bressett	Westmoreland	0.00768	2017-12-20	Knollwood Energy

RREC 17-0107	William Patnode	Westmoreland	0.00768	2017-01-20	Knollwood Energy
16-635	William Raynor	Harrisville	0.00768	2016-06-06	Knollwood Energy
RREC 17-0605	Ann Shaughnessy	Walpole	0.0076	2017-10-16	Knollwood Energy
16-1136	John Allen	Alstead	0.0076	2016-12-01	Knollwood Energy
RREC 17-0503	Keith Quarrier	Alstead	0.0076	2017-09-29	NHEC
16-698	Ron Kingsbury	Walpole	0.0076	2016-06-29	Knollwood Energy
16-258	Dean Beaman	Winchester	0.0075	2016-02-25	
16-1236	Early Beaman	Winchester	0.0075	2016-12-11	Knollwood Energy
RREC 17-0624	Hannah Bissex	Rindge	0.0075	2017-10-18	Knollwood Energy
16-0860	John Woodward	Fitzwilliam	0.0075	2016-08-19	Knollwood Energy
16-453	Richard Hill	Marlborough	0.0075	2016-04-15	Knollwood Energy
16-185	Robert Twombly	Alstead	0.0075	2016-01-22	Knollwood Energy
16-782	James Webster	Jaffrey	0.00736	2016-07-28	Knollwood Energy
16-694	Christopher Miller	Walpole	0.007	2016-06-29	Knollwood Energy
REC 15-279	James Kyle	Alstead	0.007	2015-07-09	Knollwood Energy
REC 15-223	Joe Kohler	Alstead	0.007	2015-06-08	Knollwood Energy
DE 13-364	Carol Reardon	Marlow	0.00675	2013-12-31	NHEC

16-1229	Dennis Casey	Rindge	0.00675	2016-12-11	Knollwood Energy
16-1002	Thomas Cashman	Swanzey	0.00672	2016-10-11	Knollwood Energy
RREC 17-0731	Graeme Pendock	Harrisville	0.0065	2017-11-02	Knollwood Energy
RREC 17-0959	William & Kristen Tyson	Walpole	0.0065	2017-12-21	Knollwood Energy
DE 14-286	William Coveno	Troy	0.0065	2014-10-20	Knollwood Energy
16-736	Bernd Foecking	Dublin	0.0064	2016-07-11	Knollwood Energy
16-285	Duane Schillemat	Nelson	0.0063	2016-03-07	
16-400	Diane Ammons	Troy	0.006075	2016-04-04	
16-417	Craig McNeal	Stoddard	0.00607	2016-04-07	Knollwood Energy
RREC 17-0407	James Hall	Gilsum	0.006	2017-07-10	Knollwood Energy
RREC 18-0376	John Harris	Westmoreland	0.006	2018-04-03	Knollwood Energy
16-373	John R. Figmic	Walpole	0.006	2016-03-25	
RREC 18-0545	Mark Clark	Troy	0.006	2018-06-26	Knollwood Energy
16-1056	Michael Nerrie	Walpole	0.006	2016-10-31	Knollwood Energy
16-699	Nancy Roehl	Walpole	0.006	2016-06-29	Knollwood Energy
REC 15-130	Randall Daniels	Walpole	0.006	2015-04-27	Knollwood Energy
RREC 17-0049	Richard Mellor	Rindge	0.006	2017-02-13	Knollwood Energy

16-347	Richard Trow	Walpole	0.006	2016-03-21	
REC 15-357	Robert Grenier	Walpole	0.006	2015-08-31	Knollwood Energy
REC 15-169	Ron Kingsbury	Walpole	0.006	2015-05-26	Knollwood Energy
16-1220	Test name: clear this	Walpole	0.006	2016-12-19	Knollwood Energy
REC 15-131	William Allen	Walpole	0.006	2015-04-27	Knollwood Energy
RREC 17-0878	Richard Drew	Richmond	0.0058	2017-11-06	Knollwood Energy
RREC 17-0619	Dan Bissex	Rindge	0.0056	2017-10-18	Knollwood Energy
RREC 17-0396	David Lagakos	Rindge	0.0056	2017-07-10	Knollwood Energy
RREC 18-0413	Paul Soltysiak	Keene	0.00551	2018-04-09	Knollwood Energy
REC 15-129	Douglas Wilkinson	Chesterfield	0.0055	2015-04-27	Knollwood Energy
RREC 17-0734	Cara Taussig	Alstead	0.00545	2017-11-03	Knollwood Energy
REC 15-056	Mike Krinsky	Marlborough	0.018	2015-02-09	Knollwood Energy
16-550	Robert Palmer	Walpole	0.014	2016-05-05	Knollwood Energy
RREC 17-0023	David Callender	Surry	0.0167	2017-02-27	Knollwood Energy
RREC 17-90109	Jason Heavner	Walpole	0.0154	2016-11-18	Knollwood Energy
16-1106	Sheldon P Scott	Walpole	0.02035	2016-11-16	Knollwood Energy
			0.818165		

System total
(MW)

0.818165

*20

*hours in a year

Capacity
factor=20%

percentage of time it operates at full power

Capacity factors (national average): overview

The capacity factor is equal to [actual ac-electricity output to the grid over a year] divided by [potential energy output at maximum rated (“nameplate”) power for all 8760 hours in a year].

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