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Envisioning a Renewable Energy Future for the Adirondack State Park

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Introduction

The Adirondack State Park is a 6 million acre parcel of protected land in northern New York State, its boundaries demarcated by the famous "blue line." It has been called ""the most advanced experiment in conservation in the United States"(Jacoby 2001), due in part to the fact that roughly 60% of its land is privately owned (Graham 1978). Because of this unique situation, there is much debate in regards to land use, conservation, and economic development. One conversation of note engages the park's energy use and emissions, a topic that brings together academics, energy professionals, and park residents alike (personal observation, Common Ground Alliance meeting, July 16, 2014). In the realm of emissions, the park has the advantage of substantial biomass in both its protected and privately owned areas, which annually sequesters upwards of 600,000 metric tons CO2e, offsetting about 30% of annual emissions (substantial additional sequestration occurs below ground, although this is difficult to quantify with present methods) (Ecology and Energy, Inc., 2009). The sequestration ability of the region is a vast economic and environmental resource, but in order to take full advantage of it the region's greenhouse gas output has to be reduced. The query that provides the basis of this work follows naturally: can the Adirondacks become a carbon-neutral or carbon negative area?

Carbon neutrality is an important concept because it challenges the current status quo of rampant greenhouse gas emission, which is undeniably causing widespread and drastic climatic effects (National Climate Assessment, 2014). Work has been done in the Adirondacks to quantify the emissions of the region. The 2009 "Adirondack Greenhouse Gas Inventory" breaks down the greenhouse gas expulsion of the Adirondacks into Scope I/direct emissions (residential, commercial, agricultural buildings, industrial, mobile sources, agricultural fugitive methane, and water treatment fugitive methane) and Scope II/indirect emissions (residential, commercial, agricultural, and industrial). It offers a primary data set that will be referenced throughout this paper as a basis for back of the envelope calculations (Ecology and Energy, Inc., 2009).

Although there are many sectors of energy use and greenhouse gas emissions, the scope of this work is meant to be focused and specific, with the intent of providing detail in one area rather than a shallow overview of many. The primary purpose of this paper is to explore ways in which home energy use in the Adirondacks can be reduced, made more efficient, and supplied through renewable sources. Reducing energy use and changing energy supplies to renewable sources are key methods of reducing greenhouse gas emissions, largely produced through the burning of fossil fuels. This report pursues these goals through the creation of a community scale energy use and supply model.

This report is broken down into a two main sections. First, it offers some current successes and projects in the renewable energy world, as well as some current obstacles. This data is largely gathered from discussion with members the Common Ground Alliance of the Adirondacks who work in the renewable energy industry, hence this section is fairly ethnographic. The CGA held an annual meeting on July 16th, 2014, and it served as an opportunity for knowledgeable individuals to come together to discuss various issues based on general topic. Many participants of the "Renewable Energy" discussion group contributed information to this paper, both at the meeting and in follow up conversations. Michael C. DeWein, New York Operations Manager for the Institute of Building Technology and Safety, discussed mobile home energy efficiency and legislative and social issues impeding renewable energy, as well as many other areas cited in this paper. Rob Riley, President of the Northern Forest Center, is working on increasing wood pellet boiler use while preserving woodlands, and also discussed biomass opportunities. Kate Fish, executive director of the Adirondack North Country Association (ANCA), and a number of plant owners offered information on small scale hydroelectric power. Finally, technical information on energy and power, including formulas used for calculations, can be attributed to previous coursework done with Dr. Julien Bouget, the Director of Investor Services with AWS Truepower, LLC, and Adjunct Professor of Environmental Science at Skidmore College.

The second, more technical part of this work explores the concept of a carbon neutral community, in which renewable energy sources feed localized micro grids, while attempting to avoid economic pressure on residents and providing energy security and self-reliance. Baseline data comes from the greenhouse gas inventory and from a study on renewable energy source implementation for New York State (Ecology and Energy, Inc., 2009, Jacobson et al., 2013). Further data is the result of personal calculations. Hence, quantitative results can be considered estimates, and not definitive. They are useful, however, for constructing the energy model outlined in this work.

I: Current opportunities for energy use reduction

Prior to delving into the energy model, it is pertinent to present some of the topics currently being discussed in the energy world. This brief section serves as a simple overview of some exciting energy projects and general topics that are occurring in the Adirondack region, with data taken from the CGA council.

The largest scale opportunity of note is the existing hydroelectric infrastructure within the blue line. Hydroelectric plants generate electricity using the power of flowing or falling water. They are generally consistent in production because unlike wind or solar power, water flow is relatively constant. Electrical production is determined mostly by the height of the dam (that is, how far the water falls) and the rate of flow. Downsides usually involve initial construction and the disruption of aquatic habitat (J. Bouget, personal communication, 2014). Luckily, the infrastructure already exists: There are 23 hydroelectric plants in or bordering the region, and many others dotting New York State (US Energy Information Administration, 2014). Large-scale plants can produce over 1,000MW (almost 6 million MWh annually), while small scale plants are in the 10-30MW range (56,000-131,000 MWh) (Jacobson et al. 2013). However, there much of the energy generated upstate is used to supplement energy use in New York City, and the National Grid gets the credit for the energy produced. Additionally, smaller scale plants are often not profitable, because hydro-electric power has been excluded from many government and NYSERDA grant opportunities, and because the availability of natural gas has driven the price of electricity down (K. Fish, personal communication, July 16, 2014). In part due to these obstacles, hydroelectric companies can generate higher profit margins by selling out of state. In short, these plants do not provide much benefit to upstate NY economically nor environmentally due to current regulatory policies. Regardless, the infrastructure needed to supply much of the region's energy through hydropower exists, and relatively little needs to be done technically to utilize this resource.

Another important existing opportunity is net metering, wherein electricity generated by an on-site installation (such as a solar panel) can be sold to the utility grid and banked against energy costs to the site. This provides opportunities to make back initial investment costs over time, and even eventually have a system pay for itself. This would provide important economic incentive to implement localized renewable energies in residential, commercial, and industrial sites. While net metering is allowed, the most optimal format is currently impeded by existing New York State legislation (M. DeWein, personal communication, July 16, 2014). Currently, net excess generation can be credited to a customer's next billing cycle, and can be sold to the grid; however, the rate is set at the utility's "avoided cost rate," which reflects the cost of delivery of the equivalent energy amount, and is thus a lower rate than retail—lowering the returns for individuals (Database of State Incentives for Renewables and Efficiency, 2014). It is vital to further incentivize renewable energy and make it an economically viable option, especially for low income areas, and making net metering more profitable for individuals is one way to do so. Both net metering and hydro-electric power are important components of a successful energy plan for the region.

A truly successful effort has been the increasing installation of wood pellet boilers. Pellet boilers are a high efficiency, centralized heating system that can be used residentially and use wood as a heat source, rather than coal, fuel oil, or electricity. The greenhouse gas emissions of wood pellets over their entire life cycle is about 82% less than coal, 80% less than gas, and 70% less than natural gas (International Wood Fuels, 2010). This conversion, therefore, has the potential to greatly reduce emissions in places where it is hard to deliver clean electricity. The ongoing challenge is to regulate the industry so that high-grade wood is not used in a manner unbefitting its quality, as well as maintain biomass in the park. The latter challenge is incentivized by the pellet industry, which needs to maintain and even increase biomass to continue sustainable use of wood material. The hope is that wood pellet boilers can provide a local alternative energy source that is less harmful in emissions, while also encouraging the careful management of wood resources (R. Riley, personal communication, July 16, 2014). While this is an important method of supplying energy, it is left out of this paper's model because it is not an electrical energy source and does not connect to an energy grid.

These are three notable examples of areas that have are encouraging both in current projects and future opportunities, although they continue to face challenges. The catalyst for these and other actions is legislative and citizen action. Organizations such as the Adirondack North Country Association (ANCA), the Common Ground Alliance (CGA), the "Cleaner, Greener Communities Sustainability Plan," and 500 other non-profit groups in the park are all working towards positive environmental change. Pressure on legislators is crucial in working towards a net-zero Adirondack Park.

Additional legal issue prevent many interesting technologies from being implemented. Wind power and biomass, for example, are limited in height of installations due to the so called "Not in My Backyard" (NIMBY) regulations. Biomass towers, for example, are limited in height in New York State to 65 feet, even though they typically need to be 100 feet to heat a commercial boiler (M. DeWein, personal communication, July 25, 2014). In cases like these, regulatory prohibitions are based on aesthetic rather than scientific grounds.

At the same time, there are many non-legislative obstacles to large scale change. Utilities are often hesitant to extend services to low income areas, and in many cases services are not provided without pressure from residents. However, interest from residents is typically low, because initial costs of switching energy sources (for example, from propane to natural gas heaters) can be prohibitively high (M. DeWein, personal communication, July 25, 2014). With neither utility companies nor residents willing to front money to change over energy sources, many plans can be stopped in their tracks before they have begun.

II: Steps to reduce energy use

While renewable energies are an essential pursuit if mankind is to sustain its existence, the best way to manage energy is to not use it at all. This next section examines ways in which home energy use can be mitigated in order to reduce energy consumption as well as greenhouse gas output inside the blue line.

Energy use reduction in Adirondack housing stock

A key area where energy use can be curtailed is in manufactured homes. Manufactured or modular homes (formerly called mobile homes) are a widespread occurrence across the United States, making up around 8% of the housing stock in the country. The Adirondack Park region, however, boasts a much higher figure—over 13% (Ecology and Energy, Inc., 2009). While manufactured homes are a cost effective option for low-income communities in the short term, they carry significant long term costs both economically and environmentally due to their startlingly high energy inefficiency. The most significant issue for manufactured homes is heating, which in general requires a staggering 40-60% more energy per square foot than the average home (Ecology and Energy, Inc., 2009). According to ANCA, the park annually spends $600 million on heating alone (Adirondack North County Association, 2014). Providing solutions and mitigations to the causes of these inefficiencies would be economically and environmentally beneficial for residents and communities. The following technical exercise seeks to use rough calculations to demonstrate the impacts certain changes might have on energy use.

Within the blue line, there are just over 40,000 households (*Adirondack Regional Assessment Project*, 2009) which annually demand around 150,000,000kWh in electricity and

31,000,000 gallons in fuel for space heating, resulting in the output of 300,000 metric tons of carbon dioxide equivalent (CO2e). This means the average home uses about 3,750 kWh and 775 gallons per year. However, the average single family home is around 1,500 ft^2, while a manufactured home is only 1,100 ft^2 (Ecology and Energy, Inc., 2009). Adjusting for this, the average non-manufactured home uses about 3,500 kWh per year, or 2.3 kWh per square foot, and 750 gallons per year or .5 gallons per square foot. Meanwhile, the average manufactured home uses around 3,795 kWh per year, or 3.45 kWh per square foot, and 950 gallons per year, or .8 gallons per square foot.

These estimates illustrate the discrepancies in energy usage between manufactured homes and other types of housing. While the smaller size of manufactured homes mitigates their overall energy use impact (that is, a 295 kWh and 200 gallon difference between manufactured homes and other housing is relatively small), the much higher use relative to area demonstrates that there is room for significant energy use reduction. The challenge is to find ways to do this without putting an economic burden on residents.

The most obvious way to reduce heating costs is through insulation and material changes. A typical manufactured home has metal walls with interior sheetrock, with minimal insulation. These metals have high conductance values, a measure of heat transfer, and low resistance values, a measure of heat retention. The type of steel sheets you might see used in a manufactured home have conductance values around 45, while insulated panels and foam have numbers like 0.03 (“Thermal Conductivity of some common Materials and Gases”). Without overcomplicating the issue, this means the difference in power loss (energy over time) is an order of magnitude lesser when using more insulating materials. This issue can be cheaply remedied by insulating walls, floors, and ceilings, especially in open spaces. In most modular homes, rooftops offer the most opportunity for insulation and modification. Flat roofs have more continuous surface area than can contribute to energy loss. Additionally, they can accumulate ice and snow in the winter which can cause cracks to form, and can alter internal temperatures of the home. Walls are problematic because there usually tends to be some form of insulation already installed, so simply installing more can be hard to do without drastic renovation. However, residing walls with more resistant materials can reduce heat loss somewhat. Extra space often exists between floors and the ground, and homes often are built without adequately insulated foundations, or without foundations entirely (M. DeWein, personal communication, July 25, 2014). Insulating this crawl space, installing side skirting, or building new homes on complete foundations with good insulation and weather treatment all offer opportunities to reduce heating loads. An especially egregious loss is through poorly made windows. Replacing windows is an expensive endeavor, but a cheaper method is to purchase plastic covers or install heavy curtains, which provide significant insulation when closed.

A second source of heat loss is ventilation or leakiness, which is a measure of hot air exiting the space through cracks, open windows, or ventilation ducts. The common culprit here is, once again, old or cheaply made windows. Simply replacing the rubber seals around windows can be significant in reducing heating loads. Similarly simple things like leaving doors and windows closed in the winter can help reduce heating loads.

By installing insulation and reducing leakiness, energy use, costs, and greenhouse gas output can be reduced by over 20% (Barakat & Chamberlin, Inc., June 1996). If every manufactured home in the Adirondacks achieved this reduction, total energy use from heating inside the blue line would be reduced by almost 400 MWh, and fuel use by almost 1 million gallons a year. These are admittedly small numbers compared to the overall energy use of the region, but they can be achieved through individual effort, with minimal monetary input.

Larger scale changes should also be implemented, with impetus placed on legislators, government, and corporations to improve the quality of housing stock in the region. While homeowners have the ability to make a significant impact on energy use and emissions, the quoted 20% reduction relies on a total collaborative effort by individuals. Frankly, the likelihood of convincing that many people to take progressive action with upfront costs seems low. Private corporations, such as manufactured home manufacturers, have the money to improve heating efficiency by producing homes with more efficient materials and heating systems. It cannot be expected that they would shoulder the financial burden of more expensive materials in the name of energy savings for their customers; neither should it be expected that economically disadvantaged residents pay more in rent or mortgages for more efficient homes. The most realistic avenue is for legislation to be passed requiring higher industry standards, and the monetary difference to be subsidized by the government. If efficiency can be incentivized for big businesses, positive change will occur.

Already in the last three or so years, the need for more efficient modular homes has been recognized, and pilot programs have shown energy savings of as much as 70% (Thurston 2013). If every manufactured home in the Adirondacks was this efficient, it would save 14,000 MWH and 3.5 million gallons of fuel annually, or the equivalent of 115,000 MWh. Complete replacement would be entirely inefficient due to all the processes involved, existing homes should be improved using steps mentioned above, as well as with new energy sources described later. However, future manufactured home buyers should be attracted to these more efficient homes. Although they cost about $30,000 more up front, (for a total $100,000 price tag), they are currently being subsidized in Vermont by non-profit organizations such as the Vermont Housing and Conservation Board which offer up to $15,000; buyers are also aided by fixed-rate bank loans and tax rebates (Thurston 2013). The potential for these homes is huge—not only are the cost-effective and save consumers money, they also reduce emissions significantly, and are more weatherproof. In short, improving the housing lot can be made affordable and energy efficient, even while making private corporations more money in the process. This is an opportunity that can benefit residents, communities, and private companies, all while reducing greenhouse gas emissions and energy consumption for the region.

Supplying Adirondack energy demand with renewable sources

A broad scale change that would have significant environmental and economic impact is further converting fuel oil usage to electricity. Of the 300,000 metric tons of carbon dioxide equivalent produced through heating, 250,000 are generated through fuel consumption of 31 million gallons of fuel. Assuming this is from standard fuel oil #2, this comes out to an annual cost of about 120 million dollars in fuel for home heating in the Adirondack region.[1]

By measuring energy output in British Thermal Units (BTU's), the industry standard, it becomes clear that fuel use is a significant source of heating energy for the park. The 31 million gallons used for space heating are equivalent to over 4 trillion BTUs, an almost incomprehensible number at face value. If all of that fuel use were to be replaced with electricity, it would require over 1 million MWh.[2]

The logical next question to examine is, can home energy needs in the Adirondacks be met with renewable sources? Taking into consideration the megawatt hour equivalent cost of space heating, water heating, and appliance and lighting demand, the total annual energy requirement for Adirondack homes is around 2 million MWh.[3]

A recent study posits that the energy demand for all of New York State could feasibly be met with a collage of renewable energy sources developed around the state.

> Under the plan, NYS's 2030 all-purpose end-use power would be provided by 10% onshore wind (4020 5-MW turbines), 40% offshore wind (12,700 5-MW turbines), 10% concentrated solar (387 100-MW plants), 10% solar-PV plants (828 50-MW plants), 6% residential rooftop PV (∼5 million 5-kW systems), 12% commercial/government rooftop PV (∼500,000 100-kW systems), 5% geothermal (36 100-MW plants), 0.5% wave (1910 0.75-MW devices), 1% tidal (2600 1-MW turbines), and 5.5% hydroelectric (6.6 1300-MW plants, of which 89% exist) (Jacobson et al. 2013).

Although this study has garnered some detractors, for a theoretical exercise such as this is provides a good baseline for the energy capabilities of different sources. It does, however, ignore natural gas, biofuels and nuclear power (this report follows suit to ensure that all work is done using the same baseline) (Gilbraith et al. 2013). With the prior mentioned goal in mind of producing electricity for the region, in the region, given energy systems can be prioritized, and others eliminated. Clearly, offshore wind, wave, and tidal energy sources can be eliminated due to basic geography. Concentrated solar, geothermal, and solar PV (photovoltaic) plants are viable, but are resource and land intensive and do not fit the small scale model imagined here. Although they should be kept in mind, they are not prioritized due to their large scale infrastructural requirements. That leaves onshore wind turbines, rooftop PV, and hydroelectric plants as the main components of this proposed energy system for the Adirondack Park region. Potential yearly megawatt outputs are compared for all sources in table 1.

Source Comparisons

[1] Costs calculated using prices obtained from the US Energy Information Administration, 2014.
[2] This assumes a kWh/BTU ratio of 1:3412 and a gallon/BTU ratio of 1:138,700
[3] Personal calculation, using baseline data from Ecology and Energy, Inc., 2009

Comparing the electrical output potential of these systems is revealing in showing the wide range in electrical potential for different systems; however, it is misleading without considering the size of these systems, the quantity that might be created, and the scale of operations. A wind turbine, for example, requires a base area of about 15m^2 and pylons extending 2-10m deep (Morgan and Ntambakwa, 2008). Multiple turbines in a plot of land require spacing between them of over 50m if they are side by side, to accommodate blades, and 15m if they are in a row, otherwise the foremost turbine will interfere with the wind arriving at the ones behind it. To meet the yearly Adirondack energy requirements solely with wind power, it would require about 200 turbines (assuming a 5MW system and a 25% capacity factor), requiring about 400mi^2.[4] This is an arguably small number in comparison to total land area—only about 4.5% of the Park's 9,375mi^2. One thing to consider is whether turbines should be grouped or isolated. While grouping turbines limits road and energy infrastructure construction, selectively placing turbines, for example at peak area elevations, allows them to supplement local, specific power requirements. A single turbine could be expected to output 10,000-17,000MWh annually depending on wind variability.

The median costs of wind power over its entire lifetime, taking into account all stages of manufacturing, assembly, etc. (this is called the levelized energy cost, or LEC), is roughly $60/MWh. Its capital cost is about $1,200/kW; its fixed operating cost $11/kW, and its variable operating cost about $6.5/MWh (Lantz et al., 2012; OpenEl Transparent Costs Database, 2014).

Space requirements for photovoltaic solar installations are on a much different scale than wind turbines. Solar panels are "sized" by kW capacity, rather than by area, but by rough estimate the average non-manufactured home in the Adirondacks could fit about 25 panels on its roof, while the average manufactured home could fit 18. The former could then fit a 5kW system using 25 panels rated at 200W, which is the rating of most common panels, which would cover roughly 90% of annual MWh requirements even if all fuel use was scrapped in favor of electricity. This assumes roughly 4 hours of available sunlight a day, on average, and a 20% capacity factor ("Calculate Solar Array Size and Cost," 2014). Manufactured homes would require panels rated at around 260kW to meet a 5kW system, which is unrealistic at current industry standards, due also in part to the solar resources of the region. 18 industry standard panels could maintain a 3.5kW system which could still meet 50% of energy requirements for manufactured homes at current efficiency ratings. With 20% energy savings for heating from homeowner efforts, the system could meet 60% of energy requirements (heating only accounting for half of all home energy use), and with high efficiency housing similar to the pilot programs in Vermont, the system could end up producing surplus energy, as much as 0.7kW per house, or 6 MWh annually. The best part about solar panels is that they in themselves do not require additional space if they are incorporated into buildings, unlike wind and hydropower. Meeting all of these benchmarks, if every manufactured home incorporated a solar array, their entire energy demand could be met, with an annually produced 30,000 MWh surplus—not enough to significantly impact power supplies, but enough to feed a modest safety net in

[4] Calculation based on spatial requirements from Jacobson et al., 2013

tandem with other sources, given proper storage technology. Solar PV has an LEC of $280/MWh, an overnight capital cost of $5,100/kW, a fixed operating cost of $32/kW, and no variable operating cost (OpenEL Transparent Costs Database, 2014). It should be noted that these costs reflect plant construction, and would be significantly lower in a residential PV system.

Finally, spatial requirements for hydroelectric plants are quite large, but given that many plants are already in existence, it is not as problematic as it might appear. Furthermore, just one hydroelectric plant has a massive output capacity—around 1,000MW, or 8,000,000MWh annually given a 93% capacity factor. This number is massive compared to the home energy needs of the Adirondack region, which is why, in part, the energy generated by plants does not remain in the region. As mentioned earlier, even if residents do not need the additional energy, the region should be able to generate income and energy credit by selling power to the state grid. Hydropower costs vary by size of the plants. A large scale project has a median LEC of $20/MWh, an overnight capital cost of $1,320/kW, a fixed operating cost of $13/kW, and a variable operating cost of $3.20/MWh. Small scale hydropower has a much different cost structure, with a LEC of $140/MWh, a capital cost of $4.50/MWh, a fixed operating cost of $130/kW, and no variable costs (OpenEL Transparent Costs Database, 2014). Costs of each energy source are compared in table 2. Small scale hydro, of course, has a much lower output capacity, often around 10MW, although the United States has seen small plants produce as much as 30MW (Canmetenergy, 2009). They also have a lower capacity factor, about 50%, producing an annual 130,00MWh. [5]

The potential for these renewable sources in the Adirondacks should not be underestimated. However, their implementation does not necessarily have to be on a region-wide scale, and in fact, smaller scale projects may fit the regions character more readily, allowing small hamlets and communities to achieve energy security using renewable sources, and increasing quality of life by reducing money spent on energy. For example, say a community was composed of 100 modular homes. At initial energy demand levels, the community would require about 6,000MWh annually. After installing insulation and taking other steps to reduce energy consumption, let's say that number drops to 4,800MWh (a 20% decrease). Any one of the aforementioned sources could cover this load. One 5MW wind turbine could supply over 3 times that amount annually, at an initial cost of about $60 per home. Small scale hydro generating 30 MW could meet 20 times this demand, but because of high initial costs, would be better suited for supplying multiple communities and home. It could potentially relatively constant power to 2,000 modular homes, at a start-up cost of about $6 million, a relatively inexpensive endeavor for that much power. Finally, solar PV could cover 60% of demand for any scale community, so long as each individual home had a PV array.

Storing and controlling electricity

[5]Calculated using 50% capacity factor given by the OpenEL Transparent Costs Database, 2014.

By looking at these energy sources, a few things become apparent. First, no one energy source should be relied on, and a variety would be beneficial to ensure success. Second, there are situations where surplus energy might be generated. Third, these sources operate on different scales, so completely isolated, community based energy production may not be the most efficient option—rather, wind and hydropower should be connected to many different communities, while solar PV should be more localized. This diversity of source and scale highlights the need for energy management, storage, and regulation of distribution, all of which can be achieved through microgrid and storage technologies.

Microgrids are small scale energy grids that can connect to other grids, but can regulate and distribute local energy independently. One of the main functions of a microgrid is independent energy storage and regulation. This means that in the event of a power outage, key components of local systems can continue to operate until the main grid is back online. So called "smart" microgrids can even reduce energy transmission inefficiencies by responding to and anticipating energy demand fluctuations, and they can be programed to manage energy use in economically advantageous ways. They reduce transmission distances from the supply source, which reduces loss over distance—the US loses about 7% of its power over transmission annually (U.S. Energy Information Administration, 2009). Most importantly, they provide a foundation for local, specific energy generation and storage, and allow for the development of eco-friendly technologies like electric car charging stations, all at a community level without banking on the impetus of national power companies developing large-scale power plants.

Microgrids are not without issue, especially when paired with renewable energy sources. Voltage distortion and fluctuation needs to be controlled. When the microgrid is feeding the main energy grid, fluctuations must be controlled if energy is to be sold to the grid. In localized, isolated grid systems, equipment such as power filters and STATCOMS ("static synchronous compensator," an automated management system) must be installed to regulate energy fluctuation (J.M. Guerrero, 2013). There is also the issue of AC/DC conversion. AC voltage is used in traditional grids, mainly because it has a much lower transportation loss. However, many renewable technologies, most notably solar PV, use DC voltage. These two different voltages have different applications, and in a system wherein various energy sources are feeding one grid, it is not unlikely that a hybrid system would have to be used, or some conversion equipment installed. DC power could be stored in local batteries, flywheels, supercapacitors, and fuel cells, while AC power could be utilized and surplus easily returned to the central grid (M. DeWein, personal communication, July 25, 2014).

The biggest obstacle impeding microgrids is utility companies themselves. They have little incentive to build microgrids because it allows communities to purchase less energy from utilities while also selling back surplus (M. DeWein, personal communication, July 25, 2014). Unless communities or private entities completely funded microgrids, utilities would have to be convinced this idea could benefit them in some way, perhaps through government incentive.

Discussion and vision

It is this author's opinion that the Adirondack region hosts a diverse and unique array of living situations, the needs of which are met by a generalized energy system. For high density areas such as Lake George, standard grid connections are necessary to meet a demand that is not only relatively high, but also highly variable as tourist season waxes and wanes. Smaller, less dense, and more remote population areas offer different challenges—rather than a system meant for high, variable demand, they need energy that is more resilient to power disruption and that does not place an economic burden on disadvantaged residents. The work done here has hopefully demonstrated that renewable energy sources offer a viable alternative to mainstream energy structures, and that they have the potential to reduce greenhouse gas emissions, reduce energy costs, and improve energy security and independence for residents.

The data presented in this paper is in service to a vision of the future, which can be achieved through concrete steps. First, existing modular homes need to be better insulated, sealed, and maintained to decrease energy use spent on heating and cooling. Second, future manufactured home installations should utilize the existing efficient technology introduced in Vermont. There is simply no excuse to provide an inefficient structure to buyers when homes can be made 70% more efficient at a 40% increased cost (Thurston, 2013). Third, all homes should be fitted with solar photovoltaic arrays to supplement home energy needs, with power going to individual homes. These first three items will have to be individual efforts, so incentive should be offered in the form of tax rebates, low-interest and subsidized loans, fixed-rate mortgages, and through education highlighting monetary savings over time. Fourth, hydro and wind power should be invested in heavily by the state government and by private energy companies, providing small scale, localized power supplies. Finally, microgrids and storage units should be created to link communities to power sources, to regulate energy between them, and to convert surplus energy to be returned to the state grid. Net metering is also an essential component of this, as it would allow for energy surplus to be properly measured and sold. These last two items are conceived as state-wide projects, although private investment would allow for an energy company to profit while residents pay a much reduced rate for electricity.

With these steps achieved, Adirondack residents, especially the economically disadvantaged ones, would pay substantially less for energy while simultaneously enjoying fewer blackouts and more control over their energy future. The small scale communities of the region could be envisioned as isolated and independent, yet interconnected by a web of energy sources feeding smart microgrids that could communicate and regulate energy use independently. At the same time, emissions from the home energy sector would be all but eliminated after initial construction.

The investment in renewable sources is essential globally, but perhaps even more so for areas like the Adirondack Park. Estimates vary, but within the next 50 years or so, current proven reserves of fossil fuels will be more or less exhausted, and even the future reserves that will likely be discovered and tapped will not last much longer (BP Statistical Review of World Energy, 2014). The sooner reliance on fossil fuels is decreased, the better. For communities in the park, pursuing energy security and some relative form of independence now is essential for quality of life for future generations. Furthermore, a switch to these relatively benign energy sources seems much preferably to other sources being explored, such as natural gas, the extraction of which is extremely controversial and not remotely proven safe for the environment nor people living near operations and adjacent waterways. In short, it is advisable to begin to invest in new energy infrastructure before it is no longer a choice.

Finally, it should be remembered that the most efficient way to use energy is not to use it at all. By producing and regulating energy locally, transmission losses are decreased. Individual behaviors and changes can allay some consumption, while large scale strategies that focus on reducing transportation inefficiencies and oil use are paramount to a carbon neutral future. This paper offers one small piece of an expansive and ever changing puzzle. Only through concentrated, large-scale, and swift efforts can the Adirondacks and the entire world provide a sustainable future for generations to come.

Figures

Table 1: Potential yearly megawatt hours provided by energy source per unit

Electrical generation	Potential output/unit (MW)	Capacity Factor (estimate)	MWh/yr/unit
Onshore wind turbine	5	0.25	135
Offshore wind turbine	5	0.45	243
Concentrated solar PV	50	0.2	1082
Residential Rooftop PV	0.005	0.2	0.1
Commercial/governmental rooftop PV	0.1	0.2	2
Geothermal plant	100	0.75	8115
Hydroelectric plant (large)	1300	0.9	10,255,997
Hydroelectric plant (small)	30	0.5	131,487

Table 2: Median associated costs of energy by energy source

	LEC (USD/MWh)	Overnight capital cost (USD/kW)	Fixed operating cost (USD/kW)	Variable Operating cost (USD/MWh)
Wind, onshore	60	1570	10.95	6.45
Solar PV	280	5100	32.03	0
Hydropower (large)	20	1320	13.14	3.2

Hydropower (small)	140	4500	130	0

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