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Feasibility of Converting New York State's Energy Production to Wind, Water and Sunlight

An Interactive Qualifying Project Report
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Section 1: Introduction

In the present day renewable resources like solar power, wind power, and hydropower have been gaining popularity among the masses. Many see them as the replacements of the coal and oil resource that are used today. A civil and environmental professor from Stanford University, Mark Z. Jacobson, has come up with multiple plans to move away from carbon fuels and ending at a point with only renewable energy resource power generation.[1] Most recently, Professor Jacobson has put forth a new plan for this alternative energy grid to be established in New York State within the next 15 years. This project has reviewed, critiqued and evaluated the feasibility of this new plan based on economics, stability, and social implications.

Renewable energy resources are gaining headway in the market as sources that do not produce pollution and are efficient replacements. The fuel of wind, sunlight and water cost nothing to run the resource, however the fuel is not always available and thus power supply for each resource is unstable. While coal, natural gas and nuclear facilities run on fossil fuels that are costly and only will increase in price as time moves on, they provide a more stable and flexible power generation. However, due to their nature, fossil fuels are limited and someday they will run out forcing society to look toward ideas such as renewable resources.

Prof. Jacobson has plans to take the world, the United States and now New York State off of these fossil fuels and onto renewable, green energy resources. Has performed tests in California to provide real world validation to his ideas and experiment whether his power generation could meet or surpass carbon based generation. While New York is the primary focus of this paper, the world plan as well as the California data will be talked about and used in the evaluation of Jacobson's alternative energy movement.

Section 2: Energy Source Background

2.1 Wind Power

Wind power is one of the most commonly known alternative energy forms in the world today. In the field of wind power there are two major forms both utilizing turbines, commercial and residential. The first is large scale wind farms that fall under the category of commercial wind power. This form entails multiple turbines in over a large area that allows for high energy production by a single organization to provide power for consumers such as a power plant would. The alternative is smaller scale residential turbine network either in turbine size, number of turbines, or both. Residential turbines are usually smaller and designed to power only a few homes in a local area at most.

2.1.1 History of Wind Power

Wind has been utilized as a source of power as far back as antiquity. The first recorded idea using the wind as a mechanical power source was by the Greek engineer Heron of Alexandria in the first century AD. The first wind capturing devices date back to the 9th century Prussia and were horizontal windmills which rotated around a vertical axis. These crude devices were used to grind grain and move water. Once the idea took hold, it spread over the known world rapidly stretching from China to Europe within a few centuries.

During the 12th century in Europe, the first vertical windmills appeared in Northern France, Eastern England and modern day Belgium. Whether the creation of the more traditional modern day vertical windmills were triggered by the inflow of Prussian ideas brought back by crusaders or the vertical windmill was created as a separate event is still heavily debated. What is confirmed however is the earliest record of a vertical windmill dates back to 1185 in Weedly, Yorkshire. These early mills were used mainly for grinding grains and water pumping such as the early mills in the Middle East.

Over the next few centuries, windmills evolved into systems that used a large post in the center of the mill attached to the sails allowing for rotation of the sails with wind direction. The first use of a drive shaft was recorded in the Netherlands during the 14th century allowing machinery outside of the main post to be able to be driven while still allowing for the free rotation of the body of the windmill. Around the same time so called “tower mills” were created which allowed for only a top cap to rotate with the wind allowing for taller structures and thus large sails. This innovation led to an increase in production even in low wind conditions due to the ability of the larger sails to capture more wind. The separated cap also led to the addition of a fantail to aid in aligning the face of the sails to the wind. The tower mills remained the standard throughout Europe until the decline with the industrial revolution and the advent of steam power.

After the decline of the industrial windmill, the windmill like wind turbine came into creation as an alternative form of electricity. The first wind turbines were built in the end of the 19th century by James Blyth in Scotland, Charles Brown in Cleveland, Ohio and Poul la Cour in Denmark which ended up becoming the power plant for a small tower. By the early 20th century, windmills were in wide use throughout Denmark and the American farmland where power distribution networks had not been set up yet. The start of the modern wind turbine began in Balaklava USSR in the 1930’s where a 100kW generator was created and operated on top of a 30 meter tower. This was followed by a wind turbine built in 1941 in Vermont that produced 1.25 MW. The large leap forward however didn’t come until the 1970’s and 1980’s with NASA wind turbine experimentations. NASA developed 13 experimental turbines creating many designs and technologies that are the basis for today’s wind power including steel tube towers, variable speed generators, composite materials, and advance controls for capturing the wind more effectively.

In 1980 the first wind farm consisting of 20 turbines was built in New Hampshire but failed when the turbines broke down and the wind resources were found to be an overestimate. Since then, the turbine has continued to be redesigned and altered in all parts from the generator to the composite materials of the blades.[2,3]

2.1.2 Maturity of the Technology

Modern horizontal wind turbines fall into two categories, large industrial turbine and small household or community turbine. Both consist of the same basic parts that work together in a complex system broken into three parts, the blades, the nacelle and the tower. The blades on a modern wind turbine have been engineered to catch the wind easily and rotate in speeds up to 55 mph on most models. The blades connect to the rotor hub which transfers the wind energy into the top of the tower known as the nacelle. The hub has an inner shaft that transfers the now mechanical energy into the gear-box. As the shaft rotates, gears a used to increase the power and turn the generator converting the mechanical energy into electrical energy. This energy is run down the inside of the tower to be added to the electrical system the turbine is on, such as the electric grid. Also housed in the nacelle is the break for the rotors, the yaw drive and controller to change the angles of the turbine and maintain operations safely. Attached to the back side of the nacelle is an anemometer to measure wind speeds and a wind vane to measure the wind direction to move the nacelle on top of the tower in order to catch the wind. For safety purposes, if the wind speed exceeds a certain limit the controller can turn the turbine to a safer position, engage the break and the pitch of the blades will become extreme forcing the blades flat to prevent damage to the system.[4]

Currently turbines have been improving drastically over the years in their output abilities. In the early 1980's, the average turbine had a rotor of 10 meters, produced 25 kW and had an annual production of 45 MWh. This improved through the years and in 1996 the average turbine rotor diameter was 40 meters with a kW rating of 550 and an annual production of 1480 MWh.[5] The new millennium saw the advent of turbines that had 71 meter rotors, ratings of 1650 kW and annual outputs of 5600 MWh. Current technology can reach power outputs of up to 5 MW per turbine for the most extreme designs but most conservative outputs for commercial usage in industrial scale turbines is around 2 MW. For households, an easily affordable and available 10kW wind turbine can generate about 10,000 kWh annually anywhere where the wind speeds average only 12 mph which is enough to power a typical household.[4,6]

Recently, turbine technology has gone back towards the idea of the original vertical turbines also known as "egg-beater" turbines as opposed to the horizontal "propeller" turbines. These turbines work in a very similar way to the original design from Prussia with a modern twist. The blades are not blades but rather airfoils. These airfoils are vertical with a bend similar to an airplane wing that causes lift to rotate around a center vertical shaft as the wind blows through the turbine. The shaft transfers the energy down the turbine to the bottom where the mechanical power enters the gear-box increasing the power. The gear-box then transfers the increased mechanical energy to the generator converting the energy into usable electricity. This presents many added benefits over the propeller design such as easy access to the majority of moving parts, ease of maintenance and repair but does cause a slight decrease in the effectiveness compared to horizontal turbines due to the additional swept area.

Currently in the United States of America the total wind generation for the start of 2010 was 51 TWh covering around 4.1 percent of the total national power consumption. It has been estimated that the total potential wind resource in United States is 10,500 GW of onshore power; the equivalent an annual potential of 37 PWh of wind power if completely harvested.[7] This would produce a total of nine times the current power consumption in the United States from all fuel sources (coal, nuclear, wind, hydroelectric). Offshore wind resources are also being analyzed with projects in Massachusetts, New Jersey, and Rhode Island all testing offshore turbine farms in order to capture more renewable energy from the wind. Current offshore technology breaks offshore turbines into three groups; shallow water (0-30m), transitional depth (30-60m), and deep water floating (60-900m) technology which are able to produce 430 GW, 541 GW and 1533 GW respectively.[4]

2.1.3 Near Future Technology

The current goal for improvement of the turbines is in the parts of the turbine. While current turbines are projected to survive roughly 20 years, the parts inside the turbine often break down and need replacing after only a few years. New materials such as carbon composites along with other materials are being looked into to construct stronger blades and gearboxes. These advancements will need to be reached if a nationwide implementation is desired to prevent bankrupting any large projects.

Looking towards the future, companies and governments are forecasting a continuation of onshore construction but a shift of attention to the offshore possibilities. Many countries have set large goals for themselves and their alternative energy plans, including wind, for the next couple of decades. The United States Department of Energy has stated that by the year 2030, 20% of the nation’s power could be supplied by wind power alone. This claim is substantial as only four percent of the nation’s power needs currently comes from wind meaning major advancements will need to be made. However, based on the technological advancements over the past decade along with the increasing popularity and funding for alternative energy the goal of 20 percent is not out of the realm of reality. [4]

Another country that has set a high goal for wind energy within the next decade is the United Kingdom. With the opening of their first wind farm in 1991, the United Kingdom has rapidly lead the way with offshore turbines creating their first offshore wind turbine farm in 2003 consisting of 20 two megawatt turbines between 7 to 8 km off of the Wales coastline. In 2007, the United Kingdome reached an output of 2GW with the addition of a 72MW wind farm in Scotland. In the same year, the government announced plans for thousands of new offshore wind turbines that could "power every home in Britain by 2020" outdoing the goal of 20% the United States put forward for 2030.[1] Currently however the project has been revised due to social and economic issues with the plan and government.[8]

2.1.4 Cost

Total monetary cost of wind production can be broken down into three categories, construction, maintenance, and removal. On average, the cost to install a single 2 MW wind turbine is approximately 3.5 million dollars providing approximately one kilowatt for around $1,750. In the case of smaller residential turbines the cost is roughly between $3,000 and $5,000 per kilowatt hour. Traditionally an average size home would require a turbine that produces 10 kilowatts meaning the cost pre turbine would range from $35,000 to $50,000 per home. After construction is completed, money would need to be put into the turbine in terms of oil for the gears, checkups by professionals and repair of any damage each year to maintain operations. Throughout the years of operation, parts would inevitably need to be replaced until the tower itself would need to be removed and a new tower installed. The total timespan required for all of the pieces of a wind turbine to be replaced essentially making the site a new turbine is an average lifespan of 20-25 years depending on the quality of the parts. However, some parts may need to be replaced over that life span; parts such as the gear box which is expected to be operation for only eight to ten years on some units.

Another cost that must be looked at is how green the turbines actually are compared to the fuels that they are attempting to replace. For turbine installation in hills, trees will need to be removed and large amounts of fossil fuel burning vehicles will be used in the construction. Inside the turbines themselves, over eight tons of iron, 11.5 tons of plastics, a 23 ton gear box and 8.5 ton generator all need to be made out of raw materials and placed into position with maintenance being performed at least years.[8]

2.1.5 Experiences

To evaluate the Jacobson plan, real world situations of the implementation of alternative energies were researched. Interviews were performed at multiple facilities to gather real world experiences and opinions of individuals who have had experience in implementing alternative energy programs. This allowed the evaluation of Jacobson's plan to take place from a more realistic as opposed to theoretical viewpoint.

2.1.5.1 Princeton Lighting Commission

The Princeton Light Commission has been attempting to operate two 1.5 megawatt Fuhrlander wind turbine since 2009. To fund the project, a $7.3 million loan was taken out and projected to be paid back through selling electricity at a rate of $90 per Megawatt. Initially when the project was first planned in 2006 it was projected that wind turbines would provide cheaper power and save the town money for other purposes after the initial startup cost. Once the project was approved however, it became plagued with problems, the largest of which was the gear-box.

The turbines had been projected to have a life expectancy of 20 years with small maintenance costs yearly but within the first year there was a catastrophic failure of one gear-box. While it was assumed that the turbine had a life expectancy of 20 years, it was known that in the industry certain parts have a much higher failure rate at earlier points throughout the wind turbine's life cycle. However, the gear box is expected to work for at least seven years, not fail within the first. The failure of the gearbox alone cost approximately $600,000 to the manufacturer company due to lack of warranty coverage. Later the following year in 2012, the manufacturer filed for bankruptcy and closed their production doors after years of success in Germany and throughout Europe but a spout of failures in the United States that forced the company to close.

To worsen the situation, the projected sale of $90 a megawatt for wind power was not achieved due to the electricity selling between $35 and $50 in the renewable energy credit market. This market operates similar to the stock market except for each unit of green energy produced, the group owning the turbine receives credits that can be traded on the variable market. Most of these markets started off strong and were a good incentive to turn green however over the past few years the market have dropped significantly and been well below expectations.

This higher cost for the turbines has tied up the town's economic resources demanding roughly 40 percent of the whole lighting commission budget yearly to maintenance and turbine failures. In 2012, only $136,000 were made on the turbines which could cover the projected average maintenance but the failures and maintenance cost of around $250,000 totaled with a spike in 2011 where the project cost $800,000 putting the lighting commission into further debt. This has largely been blamed on the cost for minor damages such as a $10,000 charge for a golf ball hitting one of the blades that required a shut done of operation and full examination of the turbine until the blade could be fixed. Other minor errors are constantly present in the turbines' daily operations adding to the increasing debt. This has become apparent in the town's electric cost as the cost per kWh for residents is 20 cents, which is about five or more cents higher than the surrounding towns.

When asked if he believed whether alternative energy of wind was possibly, the Princeton lighting commission general manager, Brian Allen, stated that he was in favor of green energy and would like to see it succeed and has heard many stories where it helped a town cut their budget, however he doesn't think that with the amount of problems present at the current time it will be a positive source of energy in his town any time soon. It has simply cost too much and failed both in practice and its projected profits.

In 2012, the Princeton Lighting Commission has decided to attempt to sell the wind turbines to a company that will rent the turbines and sell the energy to the town without removing the turbines from their current location. The deal would allow for the renting the turbines cheap enough that the company would make money and the town would slowly climb out of debt. At this point in time, the sale is still ongoing with no company desiring to buy the turbines.

2.1.5.2 Hull Windmill Project

The town of Hull, Massachusetts is comprised of 11,000 residents and an innovative wind turbine program. The turbine program started in 2001 with Hull I was a small turbine that only produced 1,600 MW annually of the town's 53,000 MW consumption for a turnkey cost of $720,000 with federal and state grants provided to aid with finances. This cost in the modern day market would be approximately double for the same device. A major factor that aided in the success of Hull starting the wind turbine program was the public support, which is generally over looked. Approximately 95 percent of the community was in support of the turbine project and moving towards green energy.

The second turbine in Hull deemed Hull II was a much larger wind turbine at 1.8 MW with an output of 4,500 MW annually compared to the Hull I which only output 1,600 MW yearly. The Hull II turbine was 110 feet tall with a total cost of 3.2 million dollars, 750,000 of which came from a foundation for moving towards green energy. Both turbines have been in successful operation for the past few years with only a transformer in the Hull II turbine needing replacement but the cost was covered by the manufacturer through a maintenance package cost that prevents the high cost seen in Princeton.

The next step for Hull is a plan to use offshore turbines and supplementing power costs in the town with other forms of alternative energy such as solar power. When asked about his view on the feasibility of wind power as an alternative energy, it was indicated by one of the project leaders, Andrew Stern, believes fully in the idea of alternative energy and believes the largest reason for the resistance is people. More people need to get on board with the idea of wind power to fully integrate it into the mainstream rather than just a form of alternative energy. He also stated that the production needs to be able to be industrialized allowing for larger amounts of cheaper turbines to be produced and thus available. For alterations to current turbines, Mr. Stern indicated that he hopes the industry will move towards lighter weight materials allowing for more production from low wind conditions and a design where the frame of the turbine is integrated into the body. Composite materials are more than likely the best current solution that is available to achieve this goal. Mr. Stern also indicated that with the advancement of stationary parts and electronics such as printed circuit boards, the cost will go down on the turbines but the overall change required will need millions of dollars in research. He believes that the industry will stay the same as it has been until something comes along that is marginally cheaper and worth the risk of testing new things. Mr. Stern was also clear on his viewpoint that wind power is not the end of the road for sustainable energy but must rather be looked at as a stepping stone until a better source can be found. Only with innovation and support can wind power truly take off and become a main form of energy rather than an "alternative" energy.

Hull succeeded where Princeton failed because of their implementation as well as their implementation. Hull was more realistic in their predictions and brought their community onto the project early. Due to this, there was a larger amount of flexibility in the purchasing of the turbine allowing for a good source to be selected. However, the biggest factor was chance and quality control. The turbines came from different companies and while the Princeton project purchased theirs from a seemingly reliable company, it was later found that the company had failed to maintain quality control forcing them to declare bankruptcy due to a large amount of failed turbines.

2.1.6 Feasibility (Pros and Cons)

If wind power is to be implemented on a grand scale the largest issue faced is the size of area required for the turbines to operate efficiently such as in Princeton. On average the space requirement between turbines is approximately four times the radius of an individual turbine. This prevents the wind patterns from being effected significantly and the power output being negatively impacted by the neighboring turbines. This negative cost of the turbine's space requirement is countered by the fact that while the turbine may be over one hundred feet wide and tall, the base on the ground is only a small portion meaning the ground below the blades can still be used for other purposes such as growing crops or grazing cattle.

The space requirement presents another issue with implementation, the wind changes and patterns in certain areas. All over the country the wind patterns vary and certain areas, such as the Midwest, are more favorable due to the topographical regularity allowing for higher wind speeds than in other areas such as mountains. This can be countered however by using turbines off the coast utilizing the ability of high winds to be produced on the ocean. Offshore turbines can be placed in areas that no one is using for other purposes and eliminate the worry of reprioritizing land. This model is what the project at cape wind is attempting to do by having offshore turbines send power back to the grid from the water.[7]

2.2 Hydropower

Hydropower, even though it is mostly confined to those places where water flows, such as rivers, lakes and oceans, it is still a renewable resource that is useful and is growing every day. This technology, people only see as being a resource for larger areas such as the ones built in Niagara Falls, the Hoover Dam, however over the past few years strides in this technology have made it more versatile and more accessible for the common person as a viable source for renewable energy.

2.2.1 History of Hydropower

Humans throughout the world have been harnessing the power generated by water for thousands of years. Before the modern turbine, waterpower was used to simplify tasks in a similar way to wind power. In the mid 1770's the first ideas on creating the modern water turbine were developed. It took until the 1880's to see the actual implementation of the first turbine when the Michigan Grand Rapid Electric and Power Company generated electricity by dynamo belting a chair factory to a water turbine. Then in 1881 Niagara Falls was used to power city street lamps in the surrounding area. As of 1889 there were two hundred electric plants in the United States using waterpower for some or all of the electricity generated. Starting in 1907 hydropower contributed to fifteen percent of the United States' electrical generation and by 1920 that number jumped to twenty-five percent. A little more than ten years later the first federal dam, Bonneville Dam began its operation on the Columbus River. In 1940 the amount of electrical generation provided by hydropower for America jumped to a staggering forty percent.[9] However, over the years with the incorporation of other fuel sources hydropower dropped once again to around ten percent of the nation's power production in the early 2000's.

2.2.2 Maturity of Hydropower

There are five different types of hydropower being used in today's world. The first type is the generic hydropower many could recognize, known as impoundment hydropower. This type of hydropower uses a dam to store water. Then the water can be released at different flow rates to either meet the changing electrical need or to keep the dam at a constant water level.

The second type of hydropower is the run of river projects, which utilizes the flow of a river to create it electrical power without having to put in an impoundment or use little impoundment such as a dam. These plants are also able to use large or small flow rates depending if the head is a high head or a small head for the plant. This type of hydroelectricity is ideal for rivers and streams that have a dry weather flow or those whose flows are regulated by a larger dam upstream. Run of the river power is also seen as one of the more environmentally friendly types due to the fact that it does not utilize a large reservoir of water, thus does not entail the risk of the storage flooding all of the lands surrounding the dam. It is also environmentally friendly due to the fact that there are fewer greenhouse gases emitted from this source of power than with other hydropower sources. This is done by the system harnessing the natural potential energy of the water in replace of being coal or natural gas to power the process. This type of hydropower is also combined with the other types such as micro hydropower to create a more sustainable source of renewable energy.

The third type of hydropower is micro hydropower. Unlike any of the other type of hydropower this type can only produce 300 kilowatts or less of energy. Even with this low yield, this smaller system is useful due to the low cost and simple set up making it ideal for individual homes or small industries. Another advantage is the ability to run independently of the grid as well as operate on the grid if desired.[10]

There are two types of turbines that can be used for this system and they are impulse turbines and reaction turbines. Impulse turbines rely on the velocity of the water to move the turbine wheel or runner. There are also two subcategories that make up the impulse turbines and those are the Pelton wheel and the Turgo impulse wheel. The Pelton wheel is a turbine that uses the concept of jet force to create the energy that moves it. Water is sent through a narrow tube at one of the turbine and then the water sprays out of the nozzle at the end of the pipe creating a force that rotates double-cupped buckets attached to the wheel. The Turgo impulse wheel is basically an upgraded version of the Pelton wheel. The concept of the jet spray is the same except the wheel is half the size and it is angled so the spray hits three buckets instead of two increasing the rotation and speed of the wheel.[11]

The last type of hydropower is the wave and tidal powered plants, which use the strong kinetic power of waves crashing up against the surface of land to produce electrical energy. Wave energy is produced when the electrical generators placed on the surface of the water and waves flow over these generators creating energy. The energy output of their generators is determined by such factors as the height of the wave, the speed of the wave, wavelength and the density of the wave. Using these generators, the wave energy can be harnessed though many different devices that operate through different principles. Some examples are pneumatic devices, buoyant devices, raft devices and spillover devices. Pneumatic devices use the motion of the wave to compress air and the drive the turbine. Buoyant devices have anchors that hold them down and when the device moves along the surface of the water on the waves it creates tension on the anchor to create energy it can harness. Raft devices use the relative motion of multiple rafts tied together on the waves to harness energy for distribution. Spillover devices do exactly as their name implies. [12]

Tidal Energy devices are much different than wave energy devices, even though they are used in a similar fashion to harness energy. These devices operate below the surface of the water and extract energy from the tides themselves. Tidal streams are predictable which allows for better placement of these devices than with wave energy devices. However tidal energy does not always match up with the hours of peak demand for energy.[12]

2.2.3 Cost of Hydropower

Hydropower is a very affordable process, along with being available and reliable. Hydropower has been measured over the years to have the lowest cost electricity over all the major fields of electrical generation such as fossil fuels and other renewable resources. For conventional hydropower, such as dams, the instillation cost for one of these sites per kilowatt would be around $1000 to $5000. For hydropower run out of a river, which is similar to the conventional hydropower, the cost would be between $1500 and $6000. As for the pumped storage systems, the cost to install them ranges from around $1000 to $4500. Wave hydropower, a new technology being developed, has an estimated cost, because it is not in high development as of right now, of around $2500. These numbers given are less or around the same for most other renewable energies making hydropower a cost effective way of creating electricity.[13]

2.2.4 Positives of Hydropower

There are many advantages to using hydropower to create electricity for the United States. One of those advantages is the range that hydropower plants have allowing output to fluctuate to the required output via flow control as the energy demand fluctuates throughout the day. This in turn allows hydropower to be good resources to meet the need of rapidly changing demands for electricity throughout the United States. Hydropower plants are also the only resource that can send power to the electrical grid directly if all the other sources of energy for an area have been disabled for one reason or another. This was proven to be an invaluable resource during the blackout of 2003 when over fifty million people from Michigan to New York lost power. However due to the fact that the hydropower plants were able to run throughout the blackout, electricity was restored to many of the people quickly. Hydropower is also a reliable resource because it can support and work in conjunction with the other renewable resources such as solar and wind power.[14]

Pump Storage is a form of hydropower that can be used with other forms of energy to store power for later use. This pump storage works by moving water from two different reservoirs at two different elevations. When there is low electricity demand the excess energy produced is used the move the water from the bottom reservoir up to the top one and when there is high electrical demand the water stored at the top reservoir is released through turbines flowing downhill. Once it gets to the bottom reservoir after flowing through the turbines, the turbines then act as pumps to push the water back up to the higher reservoir to continue the process.

2.2.5 Negatives of Hydro Power

Hydropower even with its great number of advantages still has some downsides that are affecting the prominent and widespread use as a renewable resource. One of the negatives posed by hydropower is that of its impact of the environment in which it is placed. Most hydroelectric systems in the world today are ones that use concrete dams to generate electrical energy. These dams impede on the natural flow of the waterway in which it is built. The water either is sent through the dam to the other side of the body of water or it is redistributed to another part of a flowing body of water. This blocking of the natural flow of the body of water can cause many animals to be negatively impacted. This is seen to be true with many species of fish. Fish that travel up a river to the same spot every year for mating sometimes cannot reach that spawning ground due to the dam being built. Also the animals that hunt fish along the river may lose their source of food due to the fish either not making it over the dam or getting redirected to another tributary of the body of water. There are fish ladders and other precautions put into dams now to protect the wildlife but sometimes it doesn't make a big enough impact.

2.2.6 Experiences using Hydropower

2.2.6.1 Niagara Falls

One of the mostly widely known and the one of the largest power producing facilities in the United States is the Robert Moses Niagara hydroelectric power station. This specific power station takes water from the Niagara River above Niagara Falls, runs it through the plant and then returns the water to the lower portion of the river near Lake Ontario. This power station consists of two main facilities, the Robert Moses Niagara Power Plant and the Lewiston Pump-Generating Plant. The Moses plant has thirteen turbines while the Lewiston plant has twelve. The process of the plants goes as follows; Water is diverted from the Niagara River, up to three hundred and seventy five gallons a second, and first sent to the Lewiston plant. From there the water is moved into the Moses plant where it spins the turbines powering the generators and converting the mechanical energy into electrical energy. At night when the electrical demand is not as high the Lewiston pumps transport water into the reservoir for later use. This process at Lewiston can be reversed if power demand is high and the pumps can be turned into generators to produce twice the normal amount of electricity on the day. The total amount of kilowatts generated by the plants on a normal day is around 2.4 million. As of 2012 a project has been started to upgrade the Lewiston Pump Generating Plant with new equipment, which will make the energy generated by the two plants even greater.[15]

2.2.6.2 Hoover Dam

The Hoover Dam is one of the United States' largest hydropower facilities. From 1939-1949 it was actually the world's largest hydroelectric instillation. This facility powers the states of Nevada, Arizona, and California, with a generation factor of about 4 billion kilowatt-hours of hydroelectric power. The power plant itself is located in a U shaped structure at the base of the dam and each wing of this section of the dam rises nearly 20 stories. There are two of these wings that make up the power plant structure, one is called the Arizona Wing and the other is called the Nevada wing.[16] In this facility there are seventeen main turbines, nine of which are in the Arizona wing while the other eight are in the Nevada wing. The capacity or nameplate capacity of the entire facility is around two thousand eighty megawatt. [17] This number includes the two small service stations for powering the actual plant itself. As of 2008 the average energy produced by the plant was that of 42 billion kilowatt hours per year. This number has not fluctuated much since that year and is estimated to hold steady at that for many more years to come.

2.2.6.3 Niagara Mohawk Company

Niagara Mohawk Holdings Inc., is a holding company for utilities with a long history of supplying electricity and gas to upstate New York. One of its largest subsidiaries, Niagara Mohawk Power Corporation is the second largest combined electricity and gas utility in New York State. The company started out producing and distributing its own electricity using the rivers the flow through upper state New York, however now it is primarily an energy transmitter and distributer after the sale of its power generation plants. As of late 2001 Niagara Mohawk was bought out by National Grid PLC, so as of today is a part of the ninth largest electric utility in the United States.

2.3 Solar Power

Solar power is becoming a more accessible form of renewable energy, but it still requires refinement before becoming a possible long-term solution to the energy crisis. The manufacturing of the panels is expensive as well as a lengthy process of instillation. In recent years, the technology has made immense strides toward becoming feasible as an alternative energy with lower costs and increasing efficiency. Due to this, society can now feasibly look into solar to elevate some of the dependence on fossil fuels.

2.3.1 History of Solar Power

Solar power was first introduced as far back as 1876 when a teacher and student, William Grylls Adams and Richard Day, discovered that when selenium was exposed to light, it produced energy. Almost a century later, Calvin Fuller, Gerald Pearson, and Daryl Chapin developed the first silicon solar cell in 1953. They initially developed the solar cell to solve problems with the Bell telephone system. They did not intend to make something so vital to solar power systems. They initially wanted to use selenium, but Pearson quickly realized that silicon would be of better use for the cell. After tests were done by Chapin, they discovered that silicon was five times more efficient than selenium. They ran into a problem converting the power collected by the silicon into electricity until Fuller dipped the silicon in a small amount of arsenic, which gave it a negative charge. Fuller then placed the arsenic laced silicon into a furnace to lace it with a layer of boron, which gave it a p-n junction allowing it to transfer its power.

The first commercial power cell was available in 1956. In 1973 when oil price almost doubled overnight the government attempted to lessen the United States' dependence on oil by heavily investing in solar cells among other things. The solar energy research institute was started in 1977, and in 1981 Paul Macready developed the first solar powered aircraft. The aircraft used 1600 cells and flew from France to England. In 1999 there was a breakthrough that allowed a solar cell to be developed with a photovoltaic efficiency of 36 percent.[20]

2.3.2 Maturity of Solar Power

The two main types of solar power are photovoltaic solar power, and concentrated solar power. Concentrated solar power was first developed by Professor Giovanni Francia, which was used in Sant'llario, which is near Genoa Italy in 1968. Concentrated solar power utilizes either mirrors or lenses to take large amounts of sunlight and concentrate it to a smaller area. There are four more subtypes of concentrated solar power panels. These subtypes are parabolic troughs, enclosed troughs, fresnal reflectors, and solar power towers.

Parabolic troughs are a popular form of concentrated solar power that uses a parabolic mirror to focus sunlight. The mirror is typically coated with polished aluminum and silver to increase the amount of energy captured. These panels only produce about one third of the energy that can theoretically be produced at the ideal angle with the sun and the time of day. The troughs can be aligned either with the north-south axis or the east-west axis. The north-south axis allows the rotations of the troughs to follow the sun as it moves throughout the day, which in peak times throughout the year is more advantageous. If the troughs are aligned along the east-west axis, it loses some efficiency then when they are aligned with the north-south axis, but they only need to be rotated at the change of the seasons that makes it so they do not need tracking motors. The largest solar power farm, located in Kramar Junction California, is made of parabolic troughs.

The largest solar power operation is known as the Solar Energy Generating Systems (SEGS) consisting of nine solar plants in California's Mojave Desert producing at total of 354

Megawatts. The solar plants in the SEGS system consist of two in Dagget California, four in Kramar Junction, and two in Harper Lake. The project was commissioned in 1984, and was completed in 1991.

It mainly uses solar power, but it also utilizes natural gas technology to supplement energy production to a maximum of ten percent. They only use the natural gas when there is an additional energy requirement that the solar power alone cannot provide. The mirrors SEGS use on their solar panels are 94% reflective, compared to the majority of mirrors that are only 70% reflective. Typically over the course of a year approximately 3000 panels are replaced mainly due to wind damage. To avoid damage to the panels, operators can alter the orientation of the panels on their axis during sever windstorms.

Parabolic troughs use thermocline energy cells to store the energy they generate from the sun. There other types of solar panels, but parabolic troughs with the thermocline energy cells are the most dependable of the group. Enclosed troughs are very similar to parabolic troughs. The main difference between the two is the parabolic trough takes the reflection of the sun directly, while enclosed trough traps sunlight in a glasshouse that acts like a greenhouse.

Fresnal reflectors, formally known as compact fresnal reflector technology (CLFR), are useful for its simple and robust design. It has receivers that take in solar energy that has been focused by long, flat, modular mirrors. The receivers have water flowing through a system of boiler tubes. As these tubes heat up the sunlight strikes the panels to help convert the energy into a usable resource. CLFR can be used as a standalone system, or in tandem with other energy sources like natural gas. In the standalone CLFR systems, steam is created in the boiler tubes through the extreme heat, which is used in steam turbines to create electricity. In systems that work with other resources, like natural gas, the CLFR system adds steam for the other energy system. This allows the system to produce more electricity during the sun's peak hours, but also to help reduce pollution from the plant

Solar power towers generate electricity for the grid they are connected to. The heliostats, which are sun-tracking mirrors, direct sunlight the top of a tower. Inside the tower, the heat is used in conjunction with a liquid as a medium to generate steam. The first power towers used the steam as the heat transfer liquid. Newer ones, however, use molten nitrate salt for its superior energy storage, and heat transfer qualities.

Solar power towers have a few advantages over other solar energy methods. One of these advantages is it has the best energy storage of concentrated solar energy panels. It is also is the most efficient at distributing energy to the grid during less than ideal circumstances, like on a cloudy day or at night. A single 100-megawatt tower would need 1000 acres of land to have 12 hours of storage capabilities, and be able to power 50,000 homes.

There are two major projects involving solar power towers. The first project is called solar one. It is a 10MW tower near Barstow California. From 1982 to 1988 it produced a total of 38 million kilowatts-hours of electricity. After being converted to the solar two tower, the process in which a steam medium is changed over to a molten nitrate salt, the success of the solar two tower brought interest around the world for solar power towers. The reason it sparked interest was because it delivered power to the grid 24 hours per day for nearly 7 straight days before cloudy weather interrupted operation.[21]

The second project displaying the success of the solar tower design is the Waste Isolation Power Plant (WIPP) located in New Mexico, which uses the energy to clean nuclear waste. The tower provides a green alternative to current methods used for dealing with nuclear waste through providing clean energy to power the tools used to clean the waste rather than burning fossil fuels to increase the pollution in the atmosphere. WIPP also has committed that energy consumption would be at least five percent green.[21]

The second main type of solar power is photovoltaic (PV) solar power. Some advantages of photovoltaic are their low cost and ease of installation. Photovoltaic can be installed on the roof of a building or in a freestanding solar array racks. When they are mounted a wire is run through them to connect them to a solar charge controller and to a deep cycle battery bank. If the homes energy uses DC power, the bank can be wired straight into the house. If it runs on AC power, it requires an inverter to convert the DC power into usable 120VAC power. There are four types of photovoltaic solar panels, flexible panels, unframed rigid panels, framed rigid panels, and solar roofing.

Flexible panels are virtually unbreakable in when they are used for small periods of time, for they do not use glass, but use durable UV stabilized polymers instead. They are highly heat resistant and have quick-connect terminals that are designed for external use and are UV resistant. Flexible panels are ideal for buildings like schools, hospitals, or any building that have metal roofs. Membrane roofs need to be seen individually to determine whether it would be possible to support flexible photovoltaic panels. If the membrane is in too poor condition the panels require re-roofing to work on the membrane roofs or else the panels will not remain in place. One downside with flexible panels is the amount of energy produced making them only feasibly in a small-scale energy requirement situation as opposed to large-scale operations.

Unframed rigid panels are also available for smaller projects such as the flexible panels. They are lighter than framed panels and they are cheaper than flexible panels in regards to cost per watt and durability. This cost advantage over flexible panels makes it a better choice even with the advantages flexible panels have over it such as their use for temporary projects waiting for the final solar panels to be put in place. They are better for portable applications than all types of photovoltaic panels.

Solar roofing is a newer form of photovoltaic solar energy. Any roof can be used for solar roofing panels, but some will cost more than others due to condition or type of roof. Tile and shake shingle roofs would cost more for during installation as the tiles are susceptible to breaking causing additional costs to replace broken shingles or tiles. Steep roofs would be more expensive as well for they would need more equipment and take more time to install. Flat roofs would need more racks to put the panels at the right angle to optimize intake of sunlight.

Some of the panels can mimic roof shingles. These are the most pleasing to the eye for they do not take any ground space and can seem like the roof shingles. The solar roofing panels are becoming more widespread now than they have been in the past.

The most common type of photovoltaic panels are framed rigid panels. They are the most durable photovoltaic panel and are considered by many to be the best choice for permanent or long term projects for its efficiency and durability. They are expensive but they are the best energy providing panels. Many are often made with a weather resistant junction box with quick connects.[22]

2.3.3 How Solar Panels are made

Photovoltaic panels are made mostly of silicon, which naturally releases electrons when hit by photons, which are why it is used. The problem manufacturers had to solve was how to capture the electrons and utilize the energy they create. They solved this by created two layers in the panel; one has the silicon, which is negatively charged, or high in electrons, while the lower layer is electron poor. There is a channel between the layers that allow energy to flow while the two layers force the energy to move only one way in the channel.

The energy is captured by electrical contacts on the surface of the first layer. Theses electrons are then sent through an external circuit, which provides the power for the electrical power system that is power by the solar panels. Then the electrons are returned to the bottom of the photovoltaic panel and wait for more photons strike them to start the cycle again and provide more energy.

To actually make a solar panel, there are four main steps to create the panel, crystal growing, wafering, solar cell production, and solar panel assembly. To start the crystal growing, 250 pounds of polysilicon rocks are stacked in a quartz crucible. Then you need a silicon disk with some boron on it as well. The boron ensures that the panel will have a positive potential. It is locked within a crucible with graphite-insulated walls.

The furnace then heats up to about 2,500 degrees Fahrenheit, which melts the silicon. Once the right temperature and atmospheric conditions are met, a silicon seed crystal is suspended by a rotary device and slowly lowered into the melt. The crucible starts to turn in the opposite direction than the seed crystal. The melt freezes onto the seed crystal. The crystal slowly ascends as the melt begins to accumulate as it freezes. The crystal elongates at a controlled width. After about two and a half days the crystal cools to 300 degrees Fahrenheit and is removed, ready for the next stage.

When wafering starts it begins in the cutting stage. The crystal formed earlier has its “top and tail” cut off so the crystal’s width is uniform. Wire saws cut the crystal into two feet or fewer ingots. Steel holders are placed for the next step of wafering. In the squaring stage the ingots are placed in a rack 16 at a time. A wire then sheers off four rounded segments making all their sides flat. In the slicing stage a wire wound hundreds of times in two cylindrical drums form a web of segments. The ingots are pressed against these segments to make them as thick as business cards. Every millimeter of crystal makes two wafers.

In solar cell production, etching is the first part. Etching is the only time it is necessary to have a designated clean room. The blank wafers go through intricate chemical and heat treatments that turn the wafers into productive blue cells. Then diffusing begins when the wafers are moved into long, oven like chambers where phosphorus is diffused into a thin layer of water. It is then exposed to high temperatures, which provide the negative potential. This forms a positive/negative (P/N) junction. Then, during coloring and printing, the cells are moved into trays into heavy vacuum chamber and exposed to blue-purple silicon. This is designed to reduce reflection of the energy-dense blue end of the spectrum, giving the panels their dark blue color. Metal is added to both sides adding “fingers” to the cell so the energy can be stored

The final stage is the solar panel assembly. Separate solar panels are strung together to make a row of panels for a frame. These rows are then soldered together to make them solid and less likely to break. They are then framed in the final panel where many rows are put together. Robots typically fix the rows onto the frames they will go on to. The panels are then inspected and if they pass, they are ready to be shipped to their destination.

2.3.4 Cost of Solar Panels

An average price to install a 5 kW solar panel grid is 25,000, without grants or loans. This means and average 4.71 years before you money is returned. The maintenance cost is low for most solar panels a fairly durable and only need a few checks a year. Many solar panel companies are now recycling their panels when they have lived out their lifespan. This is cheap and easy to do. Prices of installation have gone down over the years from $7.9/W for systems in 2005 to $6.2/W for systems in 2010.

2.3.5 Major Issues

One of the simplest issues to explain with solar power is the fact that some people who are against it simply are against it because of how they would look in their backyard, or the park, or wherever they would be placed. This problem isn't as prevalent as with wind or hydro power. This problem could be avoided for rooftop panels can blend in with the shingles, and there are many areas that are open and can be utilized for solar panels.

Another issue is the lack of a consistent source. Although panels can work in in climate weather, their production suffers greatly during storms, cloudy days, and of course at night. In another case, you could get an overload of sunlight. For example in 2010, Germany produced 17,320 MW of power through solar power. Spain was second with 3,892 MW. Germany at times got too much power and flooded their grid. This displays that there have been problems with controlling the flow of energy in solar panels. This also shows there is not always a reliable base load. This presents an economic instability in terms of investors who will be hesitant to commit to a radical market like solar power. If the energy produced and stored throughout the day wasn't sufficient, another power source would be needed for night time and stormy days.

2.3.6 Experiences with Solar Power

2.3.6.1 Mann Orchards

Mann Orchards in Methuen Massachusetts uses framed rigid photovoltaic panels to help provide energy to their business. The 760 panel array was manufactured by Canadian solar an installed onto a one acre plot of land behind the business for a total cost of $987,000 to complete the project. To aid in the cost, Mann Orchards received an ITC grant and Solar Renewable Energy Certificates (SREC) to help fund the project. A SREC is earned for every 1000 kilowatt hours of energy the solar system produces. SRECs can be sold on the SREC tracking system that provides revenue for the first 15 years of the project's life. The representative from the orchards stated that this is not feasible without government intervention for funding.

The extra energy created by the orchard goes into the electrical grid, which provides them energy credits by their energy provider. They also cannot fully cut off from their provider for the solar panels cannot spin an energy meter used to record the total array output to the grid without external power form the grid. This forces Mann Orchards to remain on the grid and maintain an account with their energy provider. The Orchard's electricity bill however has seen an immense decrease on the charges since the incorporation of the array.

To date, the projections for the power production of the panels have been meet and then some. Canadian solar gave the orchard an estimate of 220,400 watts with the actual yearly production around 245,000 kWh. On a smaller time scale, the panels at Mann Orchards have produced the projected amount and regularly exceed expectation. Right now the panels provide 81% of the orchards energy. They estimate the panels will pay back the money in the energy they produce in about 4.4 years. On good days throughout the summer of 2012 the panels would start producing energy at 5 AM and continue operation until 8 PM. They expect a slight drop off in the winter starting around 7 AM and finishing around 5 PM. On an average cloudy day, one of the greatest fears talked about with solar dependent plans, the panels started producing power at 8 AM and had already produced 70 KW of energy by 2 PM.

The representative from Mann Orchards said when getting and installing a solar power panel array one should get a lawyer. The legal process is not simple, and they almost lost the ITC grant through legal holdups. National Grid has a 370 page law tariff it must follow when helping a company install an array of solar panels. There would be a lot of paperwork that would need to be filed when a company is putting in solar panels.

The maintenance costs for the solar panels are very little. They only need to snow plow the space between each array. The panels are supposed to be at an angle that allows snow to slide off in the winter. The panels are durable so they rarely break so there is little cost for the Orchards in the panel's maintenance. The representative was surprised by the lack of excessive maintenance for their solar power panels.

2.3.6.2 Princeton House

In Princeton Ma, a house has two large rotating solar panels that are able to track the sun throughout the day. This moving design allows for higher production from the panels than static panels provide. The trackers were built by All Earth Renewables, while the panels were also built by Canadian Solar like the panels from the orchards (2.2.5.1).

The trackers start once there is enough light to produce energy and stop when light levels drop below power producing levels meaning there is no set time for them to start or stop. The trackers are still somewhat dependent on the grid. If the grid goes down, the panels cannot be used to power the house. There were a couple of reasons to keep the panel on the grid. One of the reasons was to gain more SRECs which are earned more quickly and larger amounts if the system remains on the grid. Another reason to stay on the grid is so they did not have to invest in a battery backup system. The cost of a backup system can easily exceed the cost of remaining on the grid especially when the most recent power bill when the interview was preformed was only ten dollars.

Currently, only two panels are on site and operational, however All Earth Renewables put the bases of two additional trackers to allow for the addition of two more tracking units to expand the array in the future.. This was done to achieve a lower total cost compared to buying each tracker system individually or in a pair.

2.3.6.3 Hardwick House

A house in Hardwick MA has two separate types of solar power, a photovoltaic system and a hot-water solar power system. The hot-water solar system makes all the hot water the home uses. The photovoltaic panels are set in a position on the roof of a home which at certain times of the year is exposed to extended sunlight.

In the summer months, the sun is too high which lowers the efficiency of the photovoltaic panels. This happens again in the winter months when the sun is too low, lowering their efficiency. So in spring and fall, the sun is in perfect position for the panels to work at top efficiency.

The hot-water panels installed provide all the hot water that the household uses. There are only two panels for this system, and it runs into a storage tank that takes the water and disperses it throughout the household.

Similar to the other locations that have been interviewed, they are still on the grid. If the grid loses power, they can no longer transfer the energy and have to go to a generator or other form of backup energy. The homeowner mentioned the fact that they could have a battery to store the energy and be able to work off the grid. The homeowner didn’t get a battery for he believes the battery defeats the purpose of solar energy; to make clean energy to reduce pollution produced by the home.

Solar power is a quickly developing form of renewable energy, but it is still more expensive than the current fossil fuel energy. Concentrated solar energy and photovoltaic solar power are the main types of solar power. There are many subtypes of both of the solar power types. Many companies are now integrating solar power into their energy systems to help them get off the grid as much as is possible. There are still many legal, economic and social challenges when installing new solar panels, especially on a large scale.

Section 3: Implementation Issues

While alternative energy strategies can be challenging to implement on a household or community scale with the existing grid, many more concerns arise when one tries to use alternative energy as the main source of energy. Unlike a combination of alternative energy and conventional power supplies, new challenges arise such as the instability of power generation levels from certain sources. These concerns include energy lost through long range transmission, the large scale economic cost compared to other energy sources and other societal concerns. All of these must be addressed for a plan to be considered realistically feasible and not simply ideological.

3.1 Stability

Whenever alternative energies such as solar and wind power are talked about in terms of being a primary source of energy, one of the largest concerns is that of the consistency of power. Unlike coal, nuclear and other forms of non-green energy, wind and solar powered systems cannot add more energy onto the grid in high demand times. While more coal or wood can be added to increase the power and more fuel rods allow nuclear power output to rise, there is no efficient way to control the wind or sunlight produced by nature.

A solution to this instability has been the goal of many advocates of alternative fuels for many years. The most straightforward solution to this problem would be energy storage in some form of battery system. While this would be a reliable form of energy storage, the materials required for these stations in large quantities and implementation cost would have to be analyzed if this solution was to be used. Comparing the effectiveness of a battery or other artificial storage system to alternative methods may prove this plan to be impractical.

For solar energy the solution of stability is especially important because while wind is variable, direct photovoltaic methods of solar power are limited to daylight hours. This however can be solved through the use of certain types of solar power plants that utilize the sun's energy during the day to heat a material that can store the energy for a continuous power generation throughout the night. Another solution that has been proposed for solving the lack of sunlight for energy at night is a mixture of hydropower and solar power. Excess solar power during the day is used to move water uphill, transforming the solar power to gravitational potential energy to be used at night for a stable source of power.

This redirection of water can also be used to alleviate the worry of hydropower stability such as during times of drought or dry seasons when the river source's power is drastically lessened. The basic solution has always been to create a reservoir behind an impound structure that can be used when water sources dry up. These reservoirs also allow for fluctuation throughout the day or year of power generation to be met. By allowing more water from the reservoir to flow through the facility, more power is produced to match the rising demand.

Wind power has the stability concern of what happens when there is no wind available for the turbines to use; just as dangerously though is when the wind is too strong for power to be safely generated without endangering the turbine. Part of the instability of the turbine's generation ability is considered when the location of the turbines is determined. Wind maps are used to analyze the average wind speeds and determine areas that have enough strong wind to produce an economically beneficial power generation.

For an implementation plan of alternative energy to be realistic, the stability issue must be considered and there should be redundancies to make sure enough power generation is produced year round. This includes the variable loads throughout the day and throughout the year such as the increase during summer and winter due to climate-controlled houses that strain even the current fossil based fuel systems.

3.2 Transmission

Once a stable form of energy can be achieved though, the next concern arises, moving the energy from the source to where it is needed. While this has been dealt with through the use of massive wire grids throughout the country with fossil and nuclear fuels, new challenges arise when looking at implementation of an alternative energy system.

One of the primary issues that arise is the fact that the current grid does not provide an effective tool for alternative energy and would have to be altered severely to adjust to the incorporation of green systems due to locations of the power sources. Currently, the national power grid is actually made up of three separate regional grids; the Western Interconnect, Eastern Interconnect and the Texas Interconnect. Each of these grids works almost independently of the others without the ability to move significantly large amounts of electricity between grids. This limits the implementation of widespread alternative energy resources to power population centers that are far away such as solar and wind farms in the Nevada (Western

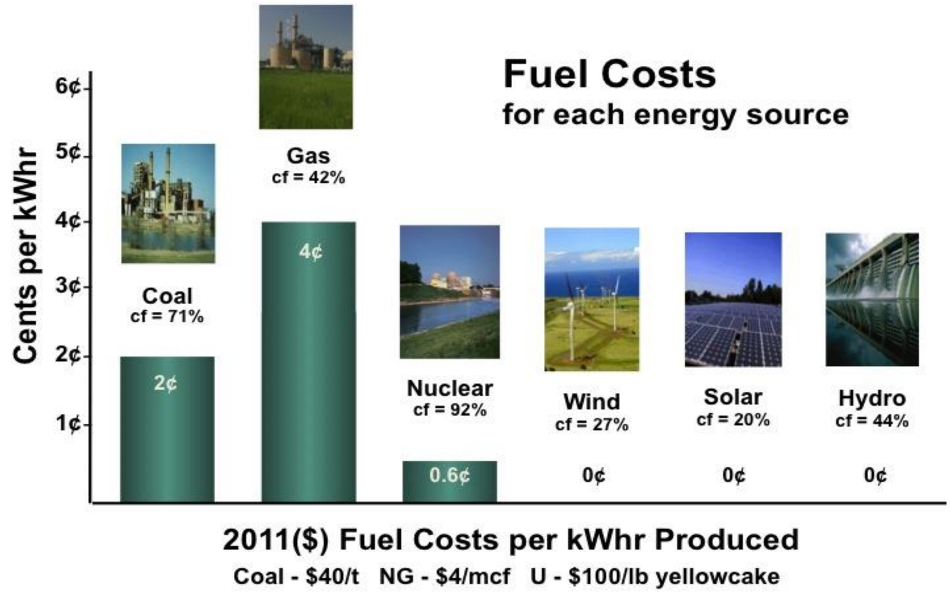
Interconnect) from powering the east coast (Eastern Interconnect). This means that within the interconnects, new systems would have to be designed to link into the areas that are suited for alternative energy sources. While coal, natural gas and other facilities can be built where they are needed, wind, water and solar facilities need to be built where the right conditions are.[23]

Within the interconnects themselves, more issues arise pertaining to the loss of electrical power moving through the cables. Electricity is lost due to the cable through three methods, the Joule effect, the corona discharge and the dielectric effect. The dielectric effect creates power loss through a portion of the energy being absorbed into the conducting material. The corona discharge is caused by the flow of electricity through the material itself leading to the creation of a magnetic field and subsequent loss as energy dissipates into the field. The Joule effect produces heat in the conducting material due to electrical flow through the wire. This is the effect that accounts for the most energy loss with up to two and a half percent in the cables and between one and two percent in the transformers. In a large scale system, this loss can account for a massive amount of energy loss such as in the case of a 1000 MW plant that loses 1%, or 10 MW, which is the equivalent of power consumed by 1,000 to 2,000 households. The loss from the lines can be compounded by the size of the transformer as medium and small transformers can have total loss of up to ten percent in extreme cases.[24,25]

While ten percent loss may be only in extreme cases, the power lost between the source and the home can be significantly higher. To combat power loss in the wires, the voltage is stepped up onto the wires and stepped down right before electricity is delivered to the customer. This is because Joule's effect is proportional to the voltage exponentially meaning by increasing the voltage, the energy lost is drastically reduced. However, before reaching the power lines, between 3-5% of the power can be lost and the same loss can be expected when the power is brought from the lines to the consumer. In the United States, the total power loss on average per year is 7.2 % of the total transmitted electricity.[25]

3.3 Economic

When it comes to undertaking any large project, the largest issue that is faced is the economic cost and without strong support this challenge can lead to the project's death. When analyzing the shift of alternative energies, many people that advocate for the movement toward alternative energies exemplify the economic strengths of alternative fuels, mainly the cost and the pollution. Many alternative energy advocates will point out how each year current fuel sources expel copious amounts of pollution into the atmosphere and environment. Compared to the cost of a clean energy source, the money used to treat pollution-related illness and the resource in manpower that is lost is a significant economic amount. However, these amounts are speculative while the only direct measurement of cost is in the cost per kilowatt-hour produced per money put into the project. As graph 1 shows, the fuel costs for coal, gas, and nuclear are much higher than the zero cost of alternative energies. While this information is true, it does not show the actual cost of the resource, or the power generated, but rather just a part of the cost.[26]

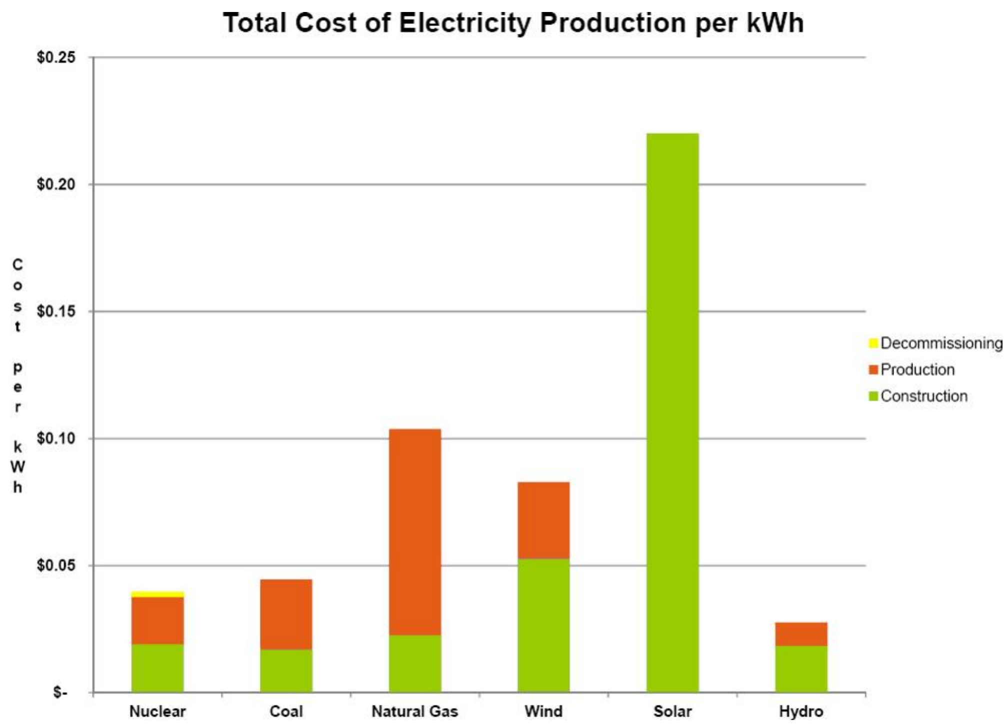


Graph 1
(http://blogs-images.forbes.com/jamesconca/files/2012/07/Fuel-Costs.jpg)

To measure the true value of power generation, one must not only take into account the cost of the fuel but also the cost of installation/construction of the energy providing source along with the maintenance cost over the lifespan of the resource. To calculate the cost for construction, the following equation was used:

$$\frac{\text{Total Construction cost}}{((\text{MW ratting x 1000}) \text{ x Useful life x } (\text{Capacity Factor X 8760})}$$

The megawatt rating was multiplied by 1,000 to convert the energy value to kilowatts and the 8,760 was the number of hours of energy production over the course of a year. While the production values may vary depending on the provider and area that the resource was used, the average was taken from multiple years of costs. With all of this information, hydropower was shown to be the cheapest but is strongly limited by the terrain requirements and the geographical locations of the dams. Coal and nuclear are the next cheapest with wind being almost double the price showing that while the alternative energies may be the cleaner form of energy, they are far from cheaper than coal. This analysis was performed in 2010 meaning it has not incorporated the recent drop in natural gas prices making natural gas once again competitive with coal, nuclear and hydropower costs. Wind power still stands at a disadvantage cost wise compared to fossil fuels by being almost double the price per kilowatt hour but is in a better position compared to solar power which is almost four times the cost of fossil fuels. With some recent developments in carbon based solar cells, this cost may drop to a level that makes solar power a competitive player in the market.[27]



Graph 2
(http://nuclearfissionary.com/2010/04/02/comparing-energy-costs-of-nuclear-coal-gas-wind-and-solar/)

Another concern economically if the price difference can be managed is the source of the money that will pay for the implementation of the new alternative power system. The question can have two solutions, either the taxpayers pay for the project through government aid or private consumers pay more allowing the power companies and private sector to pay the cost.

The project could receive government funding such as modern alternative initiatives do because the project is seen as being in the greater interest of the state, nation and population's health and safety. However, the private sector could benefit by paying the initial cost only to make it back and more over the years of successful power generation. In this method, the private sector treats the project like an investment with the goal of making back the initial investment and more over time.[23]

3.4 Societal

The social aspect of a new alternative energy plan must also be examined because public support is key in making a project on such a grand scale work. The largest opposition to alternative energies on a societal level is the "not-in-my-backyard" syndrome, also known as NIMBE. The thought process of early support as long as the plan does not hinder the individual's life is one that must be considered because on a large-scale implementation, most areas will see some change to their environment. This is one way in which non-alternative energies have an advantage over green energies, coal plants and natural gas facilities can be built away from heavily populated areas and out of sight. The NIMBE syndrome occurred during a recent alternative energy project in Massachusetts called Cape Wind. Individuals in the community supported the project until they were informed of the location of the wind turbines to be constructed. Outraged by the possible loss of their prestigious ocean view aesthetic, people started making claims that the project would affect wildlife, tourism and navigation around the cape. After a study of the projects possible impacts however, all claims of aesthetic, economical or environmental interference were disproven. The conflict between the planned alternative energy and the community illustrated how one of the largest obstacles can be the community itself when attempting new methods of power production.[23]

Another concern is in the construction of the wind turbines, solar farms or hydro plants and where they will be built. While the land may be suited for the resource, it is most likely owned by a private citizen or is a protected national land. This leads to the argument of eminent domain authority for both the location of the power instillations and for the transmission grids needed to transport power to the consumer. In 2005, an energy policy was passed that allows the Secretary of Energy to create National Interest electric Transmission Corridors in areas of congestion and constraints and grants permits for interstate transmission lines. The policy thus allows eminent domain to be used by the federal government and supersede state and local decisions. By using this act, the implementation of the system may be easier due to the ability to acquire the needed land, but on the other side it may cause opposition in the community as private landholders are forced from their properties. A possible solution though is the use of "brownfield" sites which are areas of abandoned or underused nonresidential facilities that are available for repurposing. By using these sites, the environmental degradation will be limited, as the land has already been disturbed by industry. The cost and opposition could also be cut drastically as these sites are usually lower cost and unwanted as compared to a community that would be moved through the use of eminent domain.[23]

Section 4: Mark Jacobson

4.1 Jacobson's Background & Education

Mark Jacobson is currently a professor of civil and environmental engineering at Stanford University and also the director of the Atmosphere and Energy Program run there. He teaches five courses at Stanford: Weather and Storms, Air Pollution and Global Warming: History, Science and Solutions, Air Pollution Modeling, and Numerical Weather Prediction. He also has a public online course titled "Planning for a sustainable future with wind, water, and the sun.

Along with being a professor he is also a Senior Fellow at the Woods Institute for the Environment and a Senior Fellow at the Precourt Institute for Energy, both located at Stanford University. Both the Woods Institute for the Environment and the Precourt Institute for Energy are a part of Stanford University. The main mission of the Woods Institute is to produce breakthrough environmental solutions that protect and nurture the planet to meet the vital needs of people today and for generations to come. The Precourt Institute for Energy is the hub of energy research and education at Stanford University. It was established in 2009 and their main goal is to develop energy literate leaders and communicate the practices of good energy practices through research and complimentary educational practices.

He graduated from Stanford University in 1988 with a B.S in Civil engineering, a B.A in Economics and then continued his education at Stanford obtaining a M.S in Environmental Engineering. Jacobson then went to The University of California at Los Angeles where he studied Atmospheric Science getting a M.S in 1991 and Ph.D. in 1994 in that field.[28]

Jacobson's main goal with his research is to understand severe atmospheric problems and develop solutions to those problems. His solution has come in the form of using renewable energies to power the world and lessen or completely remove society's dependence on coal, oil, or natural gas. He also has developed many models and problem solving programs to aid in his effort. In 1993 Jacobson developed the world's fastest ordinary differential equation solver for a given level accuracy for the time of its development and then went on to use this program to solve atmospheric chemistry problems. Along with the solver, that year and into the beginning of 1994 he developed the world's first air pollution model that was able to treat two-way feedback to weather and climate of gases, size, and composition-resolved aerosols. In 2001 he took what he learned from developing the previous model and created the first coupled air pollution weather climate model that could go from observations on a global scale to those on an urban scale such a close up of California or New York. This model, in later stages of its development, was used to simulate the evolution of the mixing state of aerosols, clouds, and sub-grid exhaust plumes of all aircrafts flights worldwide. He has also developed solver programs for cloud/aerosol coagulation, breakup, condensation or evaporation, freezing dissolution, chemical equilibrium, lightning, air sea exchange, greenhouse gas absorption and many more. During his research, in 2000 he discovered that black carbon might be the second leading cause of global warming after carbon dioxide. His group has also further studied the effect of absorbing organic aerosols on UV and visible radiation and the effect of aerosols on the ozone layer surrounding the planet. They have also studied the effects of both diesel and hydrogen fueled cars on the atmosphere and air quality. A lot of time has been spent by the group in most recent times developing and refining ways of using renewable energies and combing these energy sources to create a reliable source of power.[28]

In 2005, his group developed the world's first wind map using just data collected from many different sources around the globe. This standing alone was enough justification for allowing the wind component of the Repower America and Pickens Plan energy proposals to go through and allowed for the building many proposed wind farms. This wind map and allowing of the construction of wind farms was a major stepping stone in the development of Jacobson's main plan which is the wind, water, solar, (WWS) plan. This plan is founded on the ability of the world to generate all of its energy from renewable energy sources.

Jacobson with all of the research he has done and all of the solvers he has created, has been able to publish many recognized works in the scientific community, give speeches at many respectable areas of learning or political standing and receive awards for the work that he has done. To date he has published two textbooks, each published in two editions. The first book published was “Fundamentals of Atmospheric Modeling” published in 1999 and 2005. The second was “Atmospheric Pollution: History, Science, and Regulation”, published in 2002, and renamed “Air Pollution and Global Warming: History, Science, and Regulation” after its republishing in 2012.[28] He has given over 330 invited talks with that number growing every day and he has had the privilege of testifying in front of congress three times. Over a thousand different researchers from all over the world have used the computer models that he has created over the years. In 2005 he received the American Meteorological Society Henry G Houghton Award for significant contributions to modeling aerosol chemistry and to understanding the role of soot along with other carbon particles on the Earth’s climate. Jacobson’s paper “Review of energy solutions to global warming, air pollution, and energy security”, which was published in January of 2009 is one of the top all time accessed paper as of 2012 in the Journal of Energy and Environmental Sciences. He has also had the honor of serving on the Energy Efficiency and Renewables advisory committee to the U.S Secretary of Energy.[28]

4.2 Jacobson’s Works

There are a couple of papers, including the one stated above that Jacobson is very well known for and help his case when stating his ideas for wind, water and solar power across the world. One of those papers is “*A Plan for a Sustainable Future How to get all energy from wind, water, and solar power by 2030”*. He wrote this paper with Mark A Delucchi and it was published in the November issue of Scientific America in 2009.[31] The main statement of this paper is the fact that wind, water and solar technologies can provide 100 percent of the world’s energy, thus eliminating all fossil fuels. There are four key concepts put out by this paper. The first is that supplies of wind and solar on accessible land dwarf the energy consumption by people around the globe. The second is that the plan calls for 3.8 million large wind turbines, 90,000 solar plants and numerous geothermal, tidal and rooftop photovoltaic instillations worldwide. The third key concept is that the cost of generating and transmitting power would be less than the projected cost per kilowatt-hour for fossil fuel and nuclear power. The last key concept states that shortages of a few specialty materials along with lack of political will loom as the greatest obstacles to the plan put forth by this paper. After the key concepts are stated the paper goes on to talk about them in detail along with charts and figures to support all of Jacobson's proposals. This paper also does not sugarcoat anything: it states what is possible right now in terms of renewable energies and all of the hurdles that need to be overcome in order to make renewables a working and available source of energy around the world.

Another paper that is a well-known paper of Jacobson's and shows that he does have the knowledge not only on the atmospheric part of his line of study but of the energy part is his paper published in the journal "Energy Policy". This paper was written with Mark A Delucchi and is split into two parts. The first part is titled "*Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials."* [32] The first section of this paper incorporates a discussion of why Wind, Water and Solar was chosen to power the world. It starts out by presenting facts on every other type of energy already in use on the planet today and some of the problems there are with those energy sources, such as fracking, nuclear and coal power. Then the section continues by going over every type of renewable energy that could be included under the WWS branch of energy and that is including geothermal energy. Each of the types of renewable energies is given a paragraph or so going over how they run and what they entail in their use. The next section goes over the availability of the resources as presented throughout the world. There are wind and solar charts given that are composed of data from all over the globe and show precise areas of where those renewable energies would be best harnessed. The last section of the part of the paper is the discussion of the materials needed for each of the different renewables to get them up and running and the number of plants needed to run the world on that energy. Jacobson goes into great detail describing all of the materials needed for this project including steel for the wind turbine towers, silicon for the solar panels, and rare earth elements for electric vehicles to state a few of them.[32]

The second part of the paper is titled *"Providing all global energy with wind, water, and solar power, Part II: Reliability, system a transmission costs, and policies"*. The first section of the concluding part to Jacobson's paper discusses the variability and the reliability of having a one hundred percent WWS energy system covering the entirety of the world. It also covers the ability for each of the different renewable energies to back each other up in case one fails or cannot produce the needed energy for a particular day. There are two charts that are given in this section that show just that, the power generation per hours of the day. The second part of this section of the paper focuses on the transmission and energy storage of each of the renewable energies. The last section of this paper focuses on the policies issues and the needs that these renewable energies will need to follow and pass to be able to put into action.[33]

Within both of the parts of this paper, the major points for both sections are discussed in detail and have many charts or tables to back up the statements made by Jacobson. Jacobson cites many different sources in writing these sections of the Energy Policy including many of his own studies, which are included in the Appendix section of the paper for reference. This shows that he has done significant work to be able to prove his claims on how to set up the Energy Policy of the World.

4.3 Opposition & Criticism to Jacobson's Work

One person who is a strong critic of Jacobson is the blogger Charles Barton. Barton is a strong supporter of nuclear energy and its implementation in the energy system of the United States. His father was a reactor chemist at ORNL (Oak Ridge National Laboratory) and due to his close relationship with his father he gained a vast knowledge or extensive background pertaining to nuclear energy. Most of the work that he publishes on his blog is recognized by many of his peers that have technical expertise and also his work has been mentioned in the Wall Street journal. The main blog that he has created is titles "The Nuclear Green Revolution". There are multiple posts in his blog that either criticize Jacobson's work or mention other people or articles that also are critics of Jacobson.

One of the posts of his, put up on February 23 2010, is entitled "Mark Z Jacobson is Credible as a Scientist?" This post starts out by saying that when Jacobson does receive critiquing on his works from Charles and other critics he has not responded to it. He also states in this post that a large number of Jacobson's statements on nuclear and some renewables are not correct and have received widespread criticism. He continues this statement by saying that criticism is a part of science and that Jacobson instead of not responding to the criticisms should retract the faulty statements, which to the date of the publishing of the post he had not.

Along with that formally mentioned post, Barton has also posted a paper written by Bill Hannahan. He is a retired engineer and he frequently comments on post regarding Energy related issues. The paper written by Hannahan is his own revision of a paper written by Mark Jacobson and Cristina Archer titled "Supplying Base load Power and Reducing Transmission Requirements by Interconnecting Wind Farms". This revision examined a majority of the claims by Jacobson and Archer's paper and stated better ways of presenting these claims or showing their inaccuracies. This revised edition of the paper has not been published however. Hannahan sent a first draft critique to Jacobson about his paper due to the fact that it is a publicly peer edited paper and Jacobson sent back some information on the critiques made by Hannahan. However when Hannanhan sent a second set of critiques to Jacobson he ceased contact with him and the newly critiqued paper from that point on had no chance of getting through the proper channels to get published.

Jacobson's critics do have some basis for what they are talking about when they analyze his work, however it can be seen that they are not the most unbiased of critics. His critics, it can be seen for the most part, have a separate agenda that is the support and progression of nuclear power. The main blog that most of his critics follow and post to is The Nuclear Green Revolution. The Jacobson critics have a reason to not like his plan or anything submitted by him due to the fact that his plan excludes nuclear power entirely. The critics may have backgrounds in engineering or other sciences so what they are stating is true technically, but it can be seen that they are heavily favoring nuclear power and its production. When reviewing the plan presented by Jacobson critics should be taken into account but not entirely due to these facts presented in the former paragraph.

4.4 Supporters of Jacobson's Work

One supporter of Mark Jacobson and all of his research is Mark Ruffalo. Mark Ruffalo is an Academy Award-nominated actor, director, producer, screenwriter and co-founder of the organization Water Defense. This organization works to create a world where water is safe to drink, where the oceans don't rise, and the economy is powered by clean, sustainable sources of energy like wind, water, and solar. Ruffalo has spoken at Stanford University in classes that Jacobson teaches on a regular basis about his views on hydraulic fracking and the use of renewable energies. In an interview with the Progressive magazine he was quoted as saying,

> "I have spoken with Dr Mark Z Jacobson of Stanford University… We've been working on a renewable energy plan for New York that would get us off carbon-based fuels in the next fifteen years"[34]

Mark Ruffalo is one of Jacobson's major supporters and truly wants to see his plan go through because of his belief on the scientific research done by Jacobson in great detail on the subject.

Many other people, scientists and others also support Jacobson's research and scientific plans with other relations to the subject of his research like Mark Ruffalo. A list just to name a few are Robert W Howarth, Mark A Delucchi, Stan R Scobie, Jannette M Barth, Michael J Dvorak, Megan Klevze, Hind Katkhunda, Brian Miranda, Navid A Chowdhury, Rick Jones, Larson Plano, and Anthony R Ingraffea.

Robert W Howarth is a Professor of Ecology and Environmental Biology at Cornell University. He has been named one of the 250 most-cited environmental scientists in the world. He is the director of Cornel Universities Agriculture, Energy, and Environmental Program and is also an adjunct senior scientist at the Woods Hole Marine Biological Laboratory. Dr Howarth is also the chair for the International SCOPE Biofuels Project and is a past president of the coastal and Estuarine Research Federation. He has edited six books and published nearly 200 research papers. He is currently among 82 prominent scientists being considered for membership on the U.S Environmental Protection Agency's Science Advisory Board panel on hydraulic fracturing. One of his bigger positions and one of the reasons he is associated with Jacobson and his plan is the fact that he represents the state of New York on the science and technical advisory committee of the Chesapeake Bay program.[35]

Mark A Delucchi is a research scientist at the Institute of Transportation Studies at the University of California Davis. He acts as a private consultant, specializing in economic, environmental, engineering and planning analyses of current and future transportation systems. He is a member of the Alternative Fuels Committee and the Energy Committee of the Transportation Research Board. His research includes many different subjects including comprehensive analyses of the full social costs of transportation, lifecycle analyses of emissions of greenhouse gases and air pollutants from transportation systems, comprehensive assessments of alternative transportation fuels and many other fields of study that pertain to the transportation industry. He has written a couple of papers with Jacobson personally including one for Scientific America that details Jacobson's plan for making New York totally self-sufficient on renewable energies by 2030.[36]

Stan R Scobie is a retired faculty member of the Psychology Department at Binghampton University after a long 33-year career. Dr Scobies's research centered on non-human learning and memory. During his time at the University he was Associate Department Chair, Department Chair, acting Associate Graduate Dean, acting Director of Sponsored Funds and Director of the Bio-Medical Research Support Grant at B.U. He is also known for being a writer, community organizer and consultant on gas drilling issues. He has testifies before the New York State Assembly and Senate Environmental Conservation Committee, the NYS Department fo Environmental Conservation's Shale Gas Drilling Scoping Hearings, the New York City Department of Environmental Protection and at the U.S Environmental Protection Agency hearings on hydraulic fracturing. He has also played a crucial role in founding or creating several grassroots organizations such as New Yorkers for Sustainable Energy Solutions Statewide.[37]

Jannette M Barthis a graduate of John Hopkins University with both a Master of Arts and Ph.D degrees in economics from the University of Maryland-College Park. Barth has served as the chief economist of the New York Metropolitan Transit Authority for many years but no longer holds that position. She is now the president of J.M Barth and Associates, which is an economic research and consulting firm. One of her biggest focuses these days is on the economic impact of natural gas extraction due to the fact that she is a landowner in Delaware County, New York where it could occur. She has written numerous papers on the subject of natural gas extraction and the harmful effects of doing such an extraction in areas of New York such as Delaware Country.[38]

Michael J Dvorak is a Ph.D graduate in the Civil and Environmental Engineering Department at Stanford University. His main area of research is quantifying where and how much offshore wind energy exists in the US and the world. This research is being done along side Professor Mark Jacobson and he has written many research papers with Jacobson on the subject. He is currently working on quantifying the wind energy off the East Coast of the United States using the Weather Research and Forecasting Model.[39]

Megan Klevze is a second year Masters student in the Atmosphere/Energy program in the Civil and Environmental Engineering Department at Stanford University. She completed her undergraduate degrees in Environmental Systems Engineering and German at Pennsylvania State University. Before coming to Stanford she worked for three years as an environmental consultant at ENVIRON International Corporation in Arlington Virginia and this summer worked in the Air Sciences group at ENVIRON in San Francisco.[40]

Hind Katkhunda graduated Yale University with a B.S in Environmental Engineering and then went on to get an MS in Civil and Environmental Engineering at Stanford University in 2012. During her time at Stanford University she belonged to SWEP or the Stanford's Solar and Wind Energy Project. This project analyzed the potential of wind and solar projects on campus and in the bay area. One of the people she worked with in this group was Mark Jacobson. She now is currently a Product Management Intern at Enphase Energy.[41]

Brian Miranda is currently a student in the Atmosphere/Energy and Civil and Environmental Engineering Departments at Stanford University. He is expected to graduate in 205. He is working as a research assistant to Mark Jacobson. His job entails supporting the development of clean energy proposals for the Governor's Offices of New York and California that call for state economies power completely by wind, water, and sunlight.[42]

Navid A Chowdhury is currently a student enrolled in the Civil And Environmental Engineering Energy Department at Stanford University. He is expected to graduate with his degree this year in 2013.[43]

Rick Jones graduated from Cornell University with a B.S in Civil and Environmental Engineering and then went on to get his M.S in Energy Resources Engineering from Stanford University in 2012. He currently works as the Managing Principle of Hydropower services at HDR. He also has a background in water and energy resources with experience in hydropower operations and flood modeling, FERC relicensing and renewables integration studies.[44]

Larsen Plano is a second-year Master's student in the Atmospheric/Energy program at Stanford University. He has joined the green building team at the Environmental Center in New York City and helped launch the NYC Cool Roof Program. He has also helped manage the instillation of several large-scale solar hot water systems in the New York City area.[40]

Anthony R Ingraffea graduated from the University of Notre Dame in 1969 with a BS in Aerospace and Aeronautical Engineering. He then continued his education by getting a MS in Civil Engineering at Polytechnic University in 1971 and his Ph.D in Civil Engineering from the University of Colorado in 1977.   He is currently a Professor in the department of Civil and

Environmental Engineering at Cornell University. His research concentrates on computer simulations and physical testing of complex fracturing processes. He belongs to the Cornell Fracture Group which has a mission to create verify, and validate computational simulation systems for fracture control in engineered systems. He has authored with his students over 200 papers that envelop these areas of research. He has been the principle investor on over 35 million dollars in R&D projects from NASA Langley, to U,S Department of Transportation to General Dynamic and so many more. In 2011 TIME magazine named him one of its "People Who Mattered".[45]

Many of his papers stating his detailed research on atmospheric patterns, the condition on the Earth's atmosphere, and ways that it can be protected through the use of renewable energies have been cited in numerous scientific articles and papers, many of which have been published in esteemed scientific journals or magazines. This shows that people respect and look towards Jacobson's research to help progress and support their own claims on the subjects being studied. Along with that and all of the support that Jacobson has from many of the fields top researchers and students as seen above, it can be seen that Jacobson is a credible scientist when it comes to research on renewable energies and atmospheric research.

Section 5: The Plan

5.1 Jacobson's World Plan

Mark Jacobson's world plan is both ambitious and idealistic; he proposes to incorporate many types of renewable energy in the effort to make energy green. Jacobson plans for the majority of the workload to be taken by wind and solar power with hydro, wave, tidal, and geothermal filling in what necessary energy is left. Although the plan is a bit idealistic, there is merit to what Jacobson comes up with.

Jacobson plans to utilize windmill power for 50% of all the power created for the world plan, which includes the onshore windmills and the offshore windmills.[46] The windmills would all contain 5-MW wind turbines, and the wind speeds for most of the land and oceans of the world can support windmills of that size. He feels the majority of the windmills will be offshore windmills instead of onshore windmills. "The globally-available wind power over land in locations worldwide with mean wind speeds exceeding 6.9 m s^{-1} at 80 m is about 72 TW (630–700 PWh yr^{-1})".[47] Jacobson is talking about the available power for windmills on land. He feels there is enough available space around the world to produce around 72 TW a year. This is about 5 times the amount of power produced worldwide yearly and 20 times the amount of the world's electrical power production. "Good wind and solar resources over land alone can power the world for all purposes 6 and 30 times over, respectively."[48] The reason it cannot produce the entire amount needed is the land cannot only be dedicated to windmills, and a certain amount of spacing is required between 2 windmills. Another reason that Jacobson advocates windmills is they have the smallest footprints of all energy sources, green or otherwise. They do need to have certain spacing as mentioned earlier, but that space can be used for other things, like agriculture and development. So although one couldn't add another windmill in that space, the space would not become wasted area in which one couldn't do anything.

The plan has solar power accounting for 40% of all the power that is produced in the world.[46] The solar power is split up into two types, photovoltaic solar panels and concentrated solar power (CSP), which are split up evenly at 20% each to make up the 40%. Theoretically, there is about 1700 TW of photovoltaic solar power available globally throughout the year.

When you take away exclusion zones of competing land use or high latitudes, the number drops to around 8.7 GW.[47] Most of this power was created by rooftop panels, while less than 1 GW of the 8.7 GW was created by solar power plants. Jacobson believes in about 15 years, solar power technology will be able to capture more energy from the sun and keep the sunlight from being wasted. Jacobson intends to have 6% of the photovoltaic solar panels to be 3 KW roof panels while the remaining 14% would be 300 MW photovoltaic solar power plants. Jacobson is putting most of the work on the most advanced and common forms of renewable energy, wind and solar. For CSP technologies the amount available goes down for CSP needs more space to make a complex that makes the same amount of energy that photovoltaic solar power creates. Both solar power types have small footprints, that are larger than a windmills, but with no spacing necessary. Since there is not much spacing needed a solar grid can have more in one area than windmills can.

The remaining 10% of energy that would need to be produced is split between geothermal, hydro, wave, and tidal energy resources.[46] Then 4% would come from both geothermal and hydro while only 1% would come from both tidal and wave technologies. Wave and tidal technologies are not advanced enough to carry a large enough burden in the plan to be truly effective. 87% of the needed hydro is already in place in rivers and other bodies of water. Hydropower is running out of viable areas to be installed, for there is a much more limited space for hydro plants to be installed and they are all being used up. An advantage seen by many in wave, tidal, and hydro is the fact that the majority of its footprint is in the water, meaning a minimal amount of land is taken for them and this land can be used for other things. Geothermal energy is also a very area specific technology where there must be hot springs or some type of heat source that is in the ground. Most of the geothermal energy is too deep in the Earth's crust to be of any use. He states there is 0.57-1.21 PWh^{-1} a year available globally after accounting for the cost of installing and harvesting the energy.[46]

The footprint necessary to power all the on-road vehicles in the United States was calculated for wind power, solar power, nuclear power, geothermal, Corn E85, and Cellulosic E85. The study turned out that all the green energies mentioned earlier had the smaller footprints with the exception of nuclear power. Geothermal power would have a total footprint of 0.006-0.008% of the U.S land if it was used solely to power all the vehicles in the United States, while nuclear would take up 0.05%-0.062%. Solar power would take up 0.077%-0.18% of the land, while wind power would take up a total of 0.35-0.7% of the landmass. Corn E85 would take up to 9.8-17.6% of the land while Cellulosic E85 would take 4.7-35.4% of the US land to power the cars.[46]

Estimates have been made on energy demand in 2030 if the world is still on current energy resources and if the world converts completely to WWS by 2030. The end use power demand for all purposes in the world in 2010 was 12.5 TW. Predictions of this demand in 2030 with the current fuel sources that are used will be 16.9 TW. If the world switches to WWS completely, this prediction drops to 11.5 TW in 2030. This is a 32% improvement. In the United States alone, the power consumption in 2010 was 2.50 TW, which is a 37% improvement. With current power resources, that number will jump to 2.83 TW in 2030. If WWS is implemented, the predictions show this number to be 1.78 TW by 2030.

Prices for the energy resources seem to be decreasing, which increases the feasibility of the WWS plan. From 2008-2010 energy costs including transmission for onshore windmills was 4-7 cents/KWh, for offshore windmills the price was 10-17 cents/KWh. For wave energy the cost was well greater than 11 cents/KWh as it also is for tidal energy. Geothermal from 2008-2010 was 4-7 cents/KWh, and hydroelectric was a steady 4 cents/KWH. Concentrated solar power prices were around 10-15 cents/KWh from 2008-2010, while for photovoltaic solar panels, the price was 9-13 cents/KWh.

Predictions for the costs from 2020-2030 either stay the same or drop in price. Geothermal and hydroelectric's price remain the same at 4-7 cents/KWh and 4 cents/KWh respectively. Onshore windmills drop to below 4 cents/KWh in the 2020-2030 range, while offshore windmills change price to 8-13 cents/KWh in the estimates. Wave energy will drop to 4-11 cents/KWh in the predictions, and tidal will fall to 5-7 cents/KWh. Concentrated solar power will fall to a price of 7-8 cents/KWh in 2020-2030, while photovoltaic solar panels will drop to 5-7 cents/KWh in the predictions.

5.2 The California Plan

California is the greenest state in the United States when it comes to renewable energy resources. Just like in the world the plan is to integrate only clean technologies to power the state. The California effort has also been a stepping-stone and an example Jacobson has used to improve his work for New York State. New York has a similar emissions per capita number as California, making it the second greenest state already behind only California.

In a case study done in California they show how clean and renewable energy can be run throughout the day. This is an estimate on how it would look like on a typical July day[49] in 2020 if the plan was wholly accepted and implemented in California. Geothermal energy gives a steady baseline of 4 GW continuously. From the hours of 5 PM to 7 AM, wind power provides the most energy ranging from about 19 GW/hour to about 31 GW/hour in that time frame. From 7 AM to 5 PM it ranges from about 5 GW/hour to about 20 GW/hour. Solar power provides the most power during the daytime hours of 7 AM to 5 PM ranging in power production from anywhere around 6 GW/hour to around 35 GW/hour. From 8 PM to 5 AM the solar panels are inactive and in the remaining time it ranges in production from around 1 GW/hr to around 10 GW/hr. Hydropower is active every hour of the day except for 12 and 11 AM but it is not explained as to why this situation happens. It never is the lead source of energy production, but it can range anywhere from 1 GW/hr of production to around 15 GW/hour of production.

California's coasts are readily available for offshore wind farms, as well as being prime locations for them. Tests were run and it stands that the farther away from the shore the turbine is and the deeper the water is where the turbine is being placed, the turbine can take higher speeds and occupy a larger area.[50] These offshore projects could provide a large amount of clean energy for California and be able to avoid the 'not in my backyard' argument many people have against renewable resources like windmills or solar panels.

5.3 Jacobson's New York State Plan

The plan with New York State differs slightly, but still holds with wind and solar bearing the majority of the workload of the renewable resources. Jacobson is using New York State as a more specific site to show the validity in WWS. Many scenarios are possible in WWS's implementation in New York State, but one is used when describing what the different uses of the energy are taken into account. Jacobson focuses on this mix and promotes it throughout his paper.

Wind turbines will again be 50% of the resources for New York State. 40% will be offshore wind turbines, mostly off of Long Island, with the remaining 10% being onshore wind turbines. There are powerful wind tunnels just off the shore of Long Island and these will be where the majority of the offshore wind turbines will be located.[46] The percentage of the land taken up by onshore turbines in New York for this plan is 1.46% of New York State's land, and for offshore turbines it would take 4.62% of land if they were on land. These percentages include the spacing necessary between windmills in which the land unfit for windmills could be used for other means. All the wind turbines, be it onshore or offshore, would be 5 MW wind turbines.

Solar panel use drops 2% in the New York State plan when compared to the world plan to be used for 38% of the power production. "Rooftop PV in this scenario is divided into residential (5-kW systems on average) and commercial/government (100-kW systems on average)."[51] These photovoltaic solar panels will provide 18% of the 38% of the solar power production, with 6% being on residential and 12% on the commercial buildings. Another 10% of the photovoltaic solar power will be made in 50-MW photovoltaic power plants. The remaining 10% of the solar power will be made by 100-MW concentrated solar power plants. In total the solar panels would take up about 1.3% of New York's land. Jacobson does not specify where in New York these panels will be placed, only that they will take up only 1.3% of New York's land.

Then 5% of the energy would be provided through geothermal means in New York. These geothermal plants would be 100-MW plants. There would be a loss of only 0.01% of New York's land. 5.5% of the energy would be provided by 1300-MW hydroelectric power plants, with 89% of the plants already in place and producing energy for New York. 1-MW tidal turbines would provide 1% of the energy and 0.75-MW wave devices would produce the final 0.5% of the energy for New York. With all the resources that will be on land, only about 2.77% of New York's land would be taken in the WWS plan. Jacobson does not mention the area where the geothermal plants would be, just that a small percentage of energy will come from geothermal energy.

In 2010 New York State used 0.094 TW of power over the entire year. With current energy resources, that number will increase to 0.096 TW by 2030, but if WWS is widely accepted and implemented, instead of 0.096 TW the number would be 0.060 TW of power by

2030. This change is an overall 37% improvement with WWS than with current energy production methods. This decrease in consumption would be brought on by the fact that it would no longer be necessary to mine and process fossil fuels and if transportation is changed over, the electric cars can be more efficient than the fossil fuel burning types.

5.4 Resources not desired for WWS

Jacobson has a lot of faith in the WWS plan and he has reason not to trust other types of energy that are not incorporated into the WWS plan. The plan does not incorporate sources like nuclear power, coal-carbon capture and storage (CCS), Corn, and cellulosic ethanol, and natural gas. Many of these resources are considered bridge resources while the world adapts to the green renewable energy resources that will be used in the WWS plan. Jacobson has many comparisons with the WWS resources.

Compared to the efficiency of wind power, natural gas isn't as viable as a source of renewable energy. Natural gas has 50-70 times more CO_2 and air pollution than wind turbines do.[46] This puts this resource at a disadvantage environmentally speaking. "The mining, transport, and use of conventional natural gas for electric power is at least 60-80 times more carbon equivalent emissions and air pollution mortality per unit electric power generated than does wind energy over a 100-year time frame."[51] When it is compared to the current coal plants that are in place, it does improve on the amount of air pollution agents that increase the mortality of humans, but it also increases the number of global warming agents in the air. Green renewable sources like wind and solar power improve on both of these problems instead of improving one but worsening another. The process to mine natural gas is hydraulic fracking and this causes severe land and water supply degradation.[51]

Coal-CCS is a bridge resource that many believe can improve on the coal plants that are in place now. The idea of coal-CCS is to capture the carbon emissions and prevent them from escaping into the atmosphere. There isn't a true improvement and no major plants truly utilize this method of energy creation. There are 50 times more CO_2 emissions than wind, 150 times more air pollutant emissions per kWh than wind.[46] This resource requires 25% more energy to store the carbon dioxide and that also calls for a 25% increase in coal mining. This brings on more pollution for there is more transportation for the extra coal that is required to run this resource. This defeats the purpose of a supposedly improved coal system for all the reduced emissions in creation is made up for in transportation.

Nuclear power is a dangerous resource that takes a long time to be able to start up and produce energy and power.[51] The fact that there is a risk of a nuclear meltdown at any time is another factor that eliminated nuclear plants from the WWS plan. Another issue that Jacobson brings up is the fact that nuclear weapons can flourish with an increase of nuclear power plants.

The many different types of ethanol mixtures aren't as readily used as other energy resources. Corn and cellulosic ethanol don't improve gasoline pollution, and in some cases the pollution is worse than gasoline is. Corn's CO_2 emission can up to double the CO_2 emissions of gasoline, while at best it can only provide a 10% improvement. Cellulosic ethanol could increase up to 50% of the emissions of normal gasoline, while it could provide as much as a 50% decrease of emissions. Both types would need to take up a large amount of land and consume a large amount of water to work.[46]

Section 6: Evaluation of the Plan

6.1 Stability of Jacobson's Plan

One of the largest tests for Jacobson's alternative energy plans are their ability to merge the unstable green energy production into a system that can work as one. Through this, any shortcomings of one system of power generation can be covered by another source increasing power production such as the drop in solar at night being covered by an increase in hydropower and wind. In Jacobson's plans, he discusses how he would use wind, water and solar energy along with a constant geothermal production throughout the day to handle the overall fluctuation of the power requirements.

In Jacobson's plan, he references both his work in California and projects in Denmark that experimented with daily as well as seasonal power fluctuation including variable weather and extreme events. The findings were confirmed by other studies and concluded that a total of 99.8 percent of the current power requirement could be fulfilled by his wind, water and solar ideas. This was achieved through combining the alternative energy resources to cover power loss when one of the other sources dropped off due to environmental conditions.[52] By utilizing the overlap, Jacobson can prevent a loss of production throughout the system from a single resource failure and accomplishes one of the goals that a plan would need to be considered feasible.

The proof of stability however is in the numbers and comparing how much current energy is produced in conventional ways with the predicted WWS amount of energy and how many devices are needed. In his paper, Jacobson provides the table below of what his plan desires to install for energy production:

Energy Technology	Rated power of one plant or device (MW)	Percent of 2030 power demand met by plant/device	Number of plants or devices needed for NYS	Nameplate capacity of all devices (MW)	Footprint area (percent of NYS land area)	Spacing area (percent of NYS land area)
Onshore wind	5	10	4020	20,100	0.000041	1.46
Offshore wind	5	40	12,700	63,550	0.00013	4.62
Wave device	0.75	0.5	1910	1435	0.00082	0.039
Geothermal plant	100	5	36	3600	0.010	0
Hydroelectric plant	1300	5.5	6.6[a]	8520	3.50[a]	0
Tidal turbine	1	1	2600	2600	0.00061	0.0095
Res. roof PV system	0.005	6	4.97 million[b]	24,900	0.15[c]	0
Com/gov roof PV system	0.10	12	0.497 million	49,700	0.30[c]	0
Solar PV plant	50	10	828[b]	41,400	0.25	0[c]
CSP plant	100	10	387	38,700	0.60	0[c]
Total		100		254,000	4.82	6.13
Total new land required					0.96[d]	1.46[e]

Table 1.1 Jacobson's New York State Plan Broken into Devices[52]

In the table, he calculates the total energy produced by each source by taking the maximum energy production of each device and then multiplying it by the amount of devices. The total possible energy added together adds to about 254,000 MW. To calculate the total consumed figure for New York State, given in Btu's per person, the following calculation was used:

$$\frac{\text{(BTU per capita) x (population of NYS as of 2012 census) x (1 MW / 3.412.142 BTU per hour)}}{\text{365 Days x 24 hours per day}}$$

This calculation gave a total of 125,709 MW consumed by New York State.[53] This number shows that Jacobson's plan working at full efficiency could produce the consumed power, not including transmission loss, in all sectors. However, Jacobson's plan would almost never have all energy sources working at maximum efficiency. For wind alone, a study on offshore turbines in Maine using Repower 5MW turbines, the same as in Jacobson's plan, it was found that the turbines on average could only produce around 40% of the 5 MW.[54] In Jacobson's plan, the lowest possible efficiency to cover the average 125,709 MW consumption would be 50%, not an unreasonable figure but half of his planned power production relies on wind power which has been proven to be roughly 40% efficient, 10% below the needed 50%. This difference may be able to be made up for by the other forms of energy having a higher efficiency but with solar also fluctuating randomly depending on conditions, 88% of Jacobson's power production falls into this "less than maximum" efficiency region meaning when calculations were done, the maximum output under perfect conditions were used on paper, but in the real world there will be few times when these conditions are reached. If alternative energies do however drop power consumption by 37% as Jacobson claims they will, then his plan could comfortably produce the power generated as only 79,197 MW would need to be produced, or 31% of the total possible power generation of WWS. This 37% though is based in an assumption that alternative energies would require less power than carbon based fuels and up to 10% or more on power conservation measured placed upon the public.

When looking closer however at the devices themselves used to produce these overlapping power production requirements, the appearance of a challenge completed may not be as dealt with as Jacobson may have led the reader to believe. Jacobson calls for the use of 5MW onshore and offshore turbines throughout the whole plan, when in reality these structures are just now entering the market and are not in mass production to any scale that would allow this plan to commence.[55]

To make up for the off hours of solar, Jacobson states that the hydroelectric system could make up for the production drop. Stating that 89% of the needed power for the plan is already in place, this seems like a feasible notion. However, he also mentions that if this is not enough, additional hydroelectric power can be added through importing energy but fails to mention from where. In Great Britain, the alternative energy grid failed and the imported energy was French Nuclear power which if related to Jacobson's plans means that there may still have to be some fossil fuel or nuclear backups in case of emergencies.[7] The lack of a stable power supply who's power generation can be controlled even as a failsafe may prevent Jacobson's plan from being truly a pure wind, water, solar system.

Jacobson's response to the fear of a failure in the system or a drop in production is a storage system. Currently, if the load on the grid is too high for the lines to handle, alternative energy sources such as windmills and solar panels that are privately owned are blocked from adding more energy to prevent causing failures. In Jacobson plans, during peak production hours the excess production would be converted into storage through the use of batteries, hydrogen or some other forms for later use in low production times or for yearly fluctuations due to seasons. These storage locations would be at both near the production area and the consumers to limit loss of power through transmission due to placing the energy onto the gird multiple times. The hydrogen produced could be used as a fuel source for the vehicle fleet, used to heat areas or could be stored even though production of hydrogen is less effective than using the energy itself. Using hydrogen as a storage device may be a good idea on paper but hydrogen poses a serious threat due to the volatility of the gas. Special handling and storage procedures would have to be followed to ensure safety and protection of the public. Transportation of this hydrogen over large areas would require specialized trucks or containers and endanger anyone around it. In recent news, the disaster at the Fukushima Nuclear Power Plant in Japan was caused by a buildup of hydrogen, a byproduct of the zirconium rods used reacting with their environment, which destroyed the facility.[56]

To provide enough excess energy and minimize the times when power demand is less than production, Jacobson proposes to "oversize" the whole power system. The idea of having more power than what is needed would allow stability to be assured and provide the required excess for hydrogen production and storage. Through the use of excess systems, any over estimates on power generation can be covered through multiple implementations of less effective systems. With windmills, while Jacobson desires 5MW systems, in reality these systems may only produce a lower power output such as the Princeton turbine throughout the day but through additional turbines the difference will be covered.

Jacobson also implements his method for controlling the grid during variable times through the use of a demand responsive network. By redirecting power actively as it's needed, the grid would become more efficient and waste less energy through pointless transmission. The demand responsive system would also incorporate weather predictions to reduce reserve requirements. By planning using pressure systems for wind, cloud forecasts for solar power, and precipitation levels for hydropower the grid could operate more efficiently by drawing from the weather favored resource more than the others. This would also aid in keeping reserves low by allowing the planning for high wind or rain events that would allow for excess power production.

Overall, Jacobson's plan has strong points that allow for a stable power production on paper but fail to account for realistic power generation scenarios. The thought of oversizing the grid as well as demand responsive power distribution and overlapping the technologies prevents the demand from exceeding the production of the cost. However, the storage systems to be used in case of emergency or to store power for later use to deal with fluctuation should be reevaluated to provide a safer and more comprehensive analysis. Jacobson also needs to go into more detail on how the plan will be put into place, and what happens when something goes wrong. An example of this is the offshore wind power, which is projected to produce 40% of the total power for the state, according to his plan, and what would happen if there is a failure in the transmission line. From the viewpoint of stability in power production, Jacobson's NYS plan is feasible if the efficiency can be increased however during implementation the evaluation of how stable the grid is will need to be tested and a backup system should be added in case of an WWS failure.

6.2 Transmission

One of the major details looked at by Jacobson when trying to install renewable energy sources is that of transmission. When discussing his plan for California, transmission is a detail that is glanced over by Jacobson. However when discussing his world plan and his New York plan more recently, Jacobson goes into great detail on the transmission cost, implementation and the use of storage to help the transmission along.

With Jacobson's New York plan, a lot of research has been done on the case of transmission and power generation. He discusses mostly about long distance transmission due to the fact that in New York most of the facilities for wind, wave, and maybe solar will be in the outskirts of New York state. For long distance transmission, high voltage direct-current lines are common due to the fact that they result in lower transmission losses than alternating current lines. The cost of the extra-long distance transmission lines on land ranges from 0.3-3 US cents/kWh.[52] The only main barrier to the long distance transmission lines is not the cost of it but the laying down of the lines and the decision of who will pay the costs for the new lines since they will be powering the entirety of the state of New York. However, Jacobson has covered the other issues with transmission in his plan. Since most wind and all wave and tidal power will be offshore in the plan the transmission lines for the most part will be underwater and out of sight. Also he has determined methods of increasing transmission capacity of the lines which include the use of dynamic line rating equipment, high temperature low sag conductors, voltage up rating and flexible AC transmission systems.[52] With all of this data and the plan the way it is transmission should not be an issue in the future when installing these systems.

First thing analyzed by Jacobson when it comes to transmission is the use of conventional transmission meaning transmission in a conventional configured system and one that is put over distances common in practice today. When analyzing this he includes the transmission cost in with the generation cost of the electricity or power by the resources. This means that he does not have an actual transmission cost recorded, but he does include it in his final data tally. He shows the benefits of using WWS when it comes to transmission and power generation by comparing it to the typical fossil fuel energy generating systems used in most societies today. He states all the combined totals for costs per Kwh in a table that is represented by the following table.

Approximate fully annualized generation and conventional transmission costs for WWS power.

Energy technology	Annualized cost (~2007 $/kWh-delivered)	
	Present (2005–2010)	Future (2020+)
Wind onshore[a]	$0.04–0.07	≤ $0.04
Wind offshore[b]	$0.10–0.17	$0.08–0.13
Wave[c]	≥ $0.11	$0.04
Geothermal[d]	$0.04–0.07	$0.04–0.07
Hydroelectric[e]	$0.04	$0.04
CSP[f]	$0.11–0.15	$0.08
Solar PV[g]	> $0.20	$0.10
Tidal[h]	> $0.11	0.05–0.07
Conventional (mainly fossil) generation in US[i]	$0.07 (social cost: $0.12)	$0.08 (social cost: $0.14)

Table 2 "*Examining the Feasibility of Converting New York State's All-Purpose Energy Infrastructure to One Using Wind, Water, and Sunlight"* [52]

As one can see that the conventional way of power generation and power transmission which is through fossil fuels costs the average person 0.07 cents per kWh with a 0.12 cent social cost.[52] This social cost is the inclusion of damage costs due to air pollution and climate change across the world by the use of fossil fuels. Now looking at Jacobson's comparison of the renewables and the fossil fuels it can be seen that wind, wave, geothermal, hydroelectric, concentrated solar power, photovoltaic solar and tidal all cost less than the fossil fuel, this mainly being caused by the fact that fossil fuels incurs that social cost on top of its normal cost.

Jacobson when looking at the world then analyzes the cost of extra-long distance transmission. It is stated that there has been no study that has calculated the effects on cost if long distance transmission is used to transport energy from the different sources of renewable energies. Jacobson due to this fact had to make estimates based on a pre-determined length for the transmission lines and that the system is going to use high-voltage direct-current lines. With these parameters being the basis for the long distance transmission low cost, mid cost and high cost assumptions were made for the different energy sources being analyzed. The chart below shows all of the numbers given by Jacobson for all of his estimates. As can be seen he has looked into great detail on electricity transmission especially long distance transmission since more than likely those will be the transmission lines being used for the renewable energy plan. The only thing not discussed by Jacobson is where the locations of all these new transmission lines would be and where the stations that would run them would be placed.

6.3 Economic Evaluation

Mark Z. Jacobson's plan for New York alone is an ambitious one let alone the plan for the world. It takes some land to be able to finish the work that is needed for the WWS plan, but it also requires a large financial sum to accomplish be it in the world plan, the California plan, or the New York plan.

Jacobson provides a table within his New York State plan article talking about the cost each energy resource the WWS plan incorporates. They all start at a relatively higher price than the cost it would take to keep coal mines or pursue natural gas mines. He believes that if WWS is incorporated as he sees it, however, the prices of all the green renewable energy resources would either drop or, at worse, stay the same in 2 cases.

Wind power he has as costing 4-7 cents per kWh for onshore turbines and 10-17 cents per kWh for offshore turbines in the 2008-2010 time span. This is compared to the cost of coal which ranged anywhere from 7 to 10 cents per kWh in 2008. Jacobson states that all the prices he shows include any externality cost as well as transmission costs for all but residential and commercial photovoltaic solar panels. An example where wind power has been economically successful is in Scotland. Scotland produces a lot of power through wind turbines and it can overcome many of its problems if it shares the power with England. [57]

This could be a problem if Jacobson mean to use photovoltaic solar panels to power anything besides the buildings they are placed on. If they are meant to power more than that building, their cost isn't accurate for they are not including the cost needed to move the energy from the panels to the grid to wherever the power is needed. The price may change only a little, but it could change enough so that the price wouldn't seem as feasible as it originally looks like in the WWS plan. Even with the buildings they are on, they must still transfer the energy from the panels to the building. This may be built into the installation costs, but there is a cost to move the energy into the building.

Another problem with the plan is the fact that tidal and wave technologies are far from being as efficient as solar panels or wind turbines. They aren't nearly as advanced as technologies like wind turbines or solar panels. This could vastly change their price in the future when they are improved upon. Although Jacobson has a prediction on how they will cost in 2020-2030, something could come up in their development to throw off his numbers, not only in these two resources, but every resource that is being used in the WWS plan. While this is a concern in every project or undertaking, extra headroom must me worked into the budget to account for possible cost increases.

His prices for solar power panels are missing transmission costs for photovoltaic solar panels, but stand at 10-15 cent/kWh for concentrated solar power and anywhere from 9 to 13 cents/kWh for photovoltaic solar panels. These are more costly than wind turbines for their higher installation costs. Solar panels have the highest installation costs of almost any energy resource out there, which is why their cost is higher than those of wind turbines, coal, or natural gas. However, they have almost no maintenance costs, so the installation costs are all one has to pay for them, which does give them an advantage over other resources, for maintenance costs aren't one time expenditures like installation costs are. It would still take a while for the other resources to match the cost it takes to install solar panels, however, with the maintenance costs they incur. According to a study in the Wall-Street journal, and 5-kW system in Brooklyn would cost 27,500 dollars and would be able to pay for itself in 5 years.[58]

A strength in his plan for the economy is that the fuel needed to power the resources used in his WWS plan cost nothing. Air, water, and sunlight are not charged for they are a natural resource that isn't limited. The fossil fuels used today are limited and when the amount of the fossil fuel decrease their cost will increase for the demand for them would only increase as their numbers decrease. At some point, these resources will be depleted and the energy sources that rely on them will no longer be viable options for energy production so they would have to be abandoned. The cost to take down these plants would not be extremely high individually, but for the whole it would be. Eventually, after the renewable energy resources are installed, they would start to pay for themselves due to the free fuel sources they utilize, be it wind, sunlight, or water power.

Jacobson has tidal and wave technologies priced expensively right now at greater than 11 cents/kWh from 2008-2010. This shows that these technologies aren't as forward in their development as the other forms of renewable energy and are still quite costly to install and utilize. For the New York plan they only account for 1.5% of the energy production combined and that doesn't show much cost effectiveness economically. A question that could be brought up is that with such little use of these resources, could this 1.5% be spread out on the wind turbines, solar panels, and hydro plants to cut out the costs to build wave and tidal plants? It seems like the best option, for they aren't truly vital in the WWS plan. It would eliminate the uncertainty of their pricing as advances are made in the development of the two renewable energy resources. "A proposed 8000 MW tidal power plant and barrage system on the Severn Estuary in the UK has been estimated to cost $15 billion dollars."[59]

He has his solutions for the economy with the predictions for their prices dropping in the future with further development on the technologies. Jacobson and his colleagues are expecting breakthroughs in the resources to help lower installation costs, maintenance costs, and any other necessary expenditures on the technologies. If these advancements come along, as they likely will, it would back up the estimates for the costs he has for 2020-2030.

6.4 Social

There are many social issues that need to be addressed when looking at renewable energies. Some of the more important social aspect would be "not in my backyard" mentality, environmental concerns, reclaiming of private land, eminent domain, job creation, tax revenues, and pollution effects due to the non-renewable resources. On the points of not in my backyard, environmental, reclaiming of private land and eminent domain, Jacobson does not put any emphasis on them or even mention them at all. However on the social aspects of pollution effects due to non-renewable energy production, job creation and tax revenue Jacobson has done a large amount of research on that subject.

In his New York plan Jacobson lays out the entire cost reduction on air pollution and global warming due to the use of WWS. As stated by Jacobson, conversion to a WWS infrastructure would reduce air pollution mortality and morbidity, health costs associated with mortality and morbidity, and global warming costs in New York State. The way the air pollution mortality is estimated is in two ways, the top down approach and the bottom up approach. The top down approach looks at the bigger picture, such as the United States, and then generalizes it down to the smaller picture, which in this case would be New York State. He has compiled much data on the mortality rate of New Yorkers due to pollution as shown in the table following this.

New York region.

	Annual Premature Mortalities due to Ground-Level Ozone		
	Low Estimate	Medium Estimate	High Estimate
Region 1	55.1	110	164
Region 2	103	205	306
Region 3	37.7	75.1	112
Region 4	10.7	21.4	32.0
Region 5	26.5	52.8	78.9
Region 6	8.4	16.8	25.1
Region 7	18.9	37.7	56.4
Region 8	15.8	31.5	46.8
Region 9	80.8	164	244
TOTAL	**356**	**713**	**1070**

Table 3 "*Examining the Feasibility of Converting New York State's All-Purpose Energy Infrastructure to One Using Wind, Water, and Sunlight*" [52]

As calculated by Jacobson and his colleagues the total social cost due to air pollution mortality, morbidity, lost productivity, and visible degradation in New York State is estimated around 33 billion dollars a year, with ten million dollars being spent on every death of someone at least on the upper end of the calculation. Also the fossil fuel emitted in the state will also contribute directly to the United States global warming costs by adding 1.7 billion dollars to the total spending each year.[58] Jacobson believes that with the instillation of WWS energy systems that this entire cost by the state of New York and the United States will disappear completely. This is argued by his calculating that state with the amount of money being spent and then saved by the instillation of WWS the payback time for the state of New York will be around 16 years, that being the high estimate.

The second social aspect analyzed well by Jacobson is that of job creation in New York State exclusively. He separately analyzes every renewable resource and its individual contribution to the job market. He starts off with onshore and offshore wind farm production. With the development of the onshore wind farms it is calculated that they will create 61,300 full time jobs and from that point here after create 2,260 annual full time jobs.[58] With offshore wind farms it's estimated that they will create 320,000 full time jobs and from that point create 7,140 annual full time jobs.[52] Next Jacobson analyses job creation within all of solar power. The concentrated solar projects have been estimated to create 401,000 full time jobs during their construction and 15,700 full time jobs post construction.[52] Solar photovoltaic plants are estimated to create 1,160,000 full time jobs during construction and 5690 full time jobs post construction. Rooftop photovoltaic systems are estimated to create 2,420,000 full time jobs during construction and 9,620 full time jobs after construction.[52] Finally in concerns with his WWS plan even though he does go over geothermal energy, the last renewable energy to be analyzed for job creation is Hydroelectric, Tidal and Wave energy. For hydroelectric power it can be estimated that 2,360 additional post construction jobs will be created and that is assuming 2-3 full time jobs are created per MW of hydropower generated.[2] For wave power it is estimated that 7,200 construction jobs will be created and 161 annual permanent jobs will be needed per year after the construction of the system.[2] For tidal power 14,100 construction jobs are estimated to be created and 292 annual permanent jobs will be needed per year after the construction.[52]

With all these jobs being created by the renewable energies, the amount of money that is put into the New York state economy will increase greatly and the lives of all the people in the state will improve. This will improve the social standing of both New York state and renewable energies as a whole.

The last social aspect analyzed by Jacobson is that of state and local tax revenues. The increase in jobs in the state due to the construction and instillation of the renewable energy facilities will increase the personal income tax receipts of the people in New York State. Also because of the increase in the standard of living of the people of the state people who live there will also receive higher property tax revenues than under the current infrastructure of non-renewable energies.

Section 7: Suggestions for Plan Improvement

While Jacobson's plan is the embodiment of a feasible move from fossil fuels to alternative energy for the State of New York, there are a few alterations that would improve the feasibility and realism of seeing New York on a carbon-free system. These minor changes and additions come from the evaluation of the plan and with incorporation bring the plan full circle into a realizable goal. These suggestions include social, stability, and technological thoughts to consider.

The first suggestion has to do with all the parts omitted from Jacobson's plan to implement the new alternative energy system. Costs associated with construction, funding of the overall project, and enforcement of the new energy conservation laws put forth are just a few areas that Jacobson needs to actually evaluate out and lay down a plan for how to manage these expenses. The large omission from the paper that should be considered is the argument of the location of the facilities themselves. While the total area is shown in the plan for each resource, the actual location is not considered. If the locations of the facilities or even the rough area that the plants would be built were mapped out, then a multitude of costs for the alternative energies could be calculated. This information would also allow for the social and economic aspect of eminent domain to be taken under consideration. Knowing the location, then mapping out the required power lines would show private lands that would need to either be bought or convinced to allow alternative energies or transmission lines to be placed on the land. On paper such as in Jacobson's plan this major issue was addressed through claims that these problems would be dealt with in the "planning phase" but for Jacobson's plan to be feasible he must address these issues and propose at least some solution.

The next major issue that Jacobson has to address is the limit of current technology compared to his idealistic view on the power grid. While he was able to prove that he can output an amount sufficient enough to replace the output of carbon-based grids, he failed to go into depth on the solution he stated would be instrumental in lowering the cost and resistance of power. Jacobson should have added in a section describing his research into future technologies and current companies perusing these endeavors. This includes the statement claiming the transmission loss will decrease with new materials in the future or the lowering of costs through innovation in solar and wind generation. Jacobson could have mentioned movements being made toward carbon solar panels that will decrease the cost of production and eliminate the resource requirement of sulfur or how the increase in higher tensile materials and printed circuit board technology will drive the cost of wind turbines down.

A major concern that the over engineering of Jacobson's grid corrects is the stability of the production. However, having a small fossil fuel or nuclear backup rather than complete removal may be a better tactic to provide constant power. These plants would need to run continuously to provide stability to the power supply and in cases of emergency eliminate the time required to bring power plants online. This would require people at the facilities to monitor the power production and accommodate the fluctuation. The flux and strain placed on the grid through manipulation of alternative energies, especially those that cannot be directly controlled by humans, can lead to blackouts throughout a power grid. This effect has been proven in the one place that Jacobson pulls most of his data from, California. In San Francisco, the grid has been put under a higher level of stress because of alternative energies and thus made more fragile.[60] Due to the wild fluctuations of the power production, sharp increases in power threaten to trigger blackouts. In the region, conventional power plants are used to maintain stability in the grid. However, recently the levels of consumption have made the amount of conventional plants per unit power consumed lower meaning a higher reliability on solar and wind. This brings to light an issue because the total amount of power produced has to match the consumed power or else the voltage sags and will cause rolling blackouts and with a higher reliability on the sharp fluctuating alternative energies, the reactive ability of the gird is lessening. The problem in this situation is not capacity, which Jacobson talks about at length, but rather the fluctuation. Outside of stating the conversion of additional energy produced to storage methods such as hydrogen; which is extremely dangerous in high amounts and other storage methods should be considered for safety and efficiency; there is no mention of how to manage the fluctuation through the grid, only the capacity fluctuation.[60] While Jacobson's plan is to move New York State completely to alternative energy, California is facing a more fragile power system though the implementation of wide scale solar and wind power showing that fluctuation rather than capacity may be the larger issue. To improve the realism and feasibility of his plan, Professor Mark Jacobson must address this dangerous fluctuation threat being experienced in California.

Section 8: Conclusion

The New York State WWS Plan proposed by Professor Mark Jacobson puts forth an interesting scenario and does lay the ground work for possible movement forward on his ideas. He explains how to move from a power grid reliant on current day conventional methods of power generation to a grid supplied only by relatively clean energy with the only cost to the environment being the land loss and materials required to construct and install the power stations. However, with a deeper analysis using real world experiences to evaluate the feasibility of implementation, it was concluded that the plan was too optimistic in its predictions to succeed. This conclusion was based off of the lack of discussion on many issues that are currently faced by individuals and communities who have taken the steps towards moving themselves towards a world that is set out in Professor Jacobson's NYS plan. These issues of alternative energies included the NIMBY syndrome, land rights, consistent energy production considering capacity factors, as well as how to enforce the "energy measurements" that would force citizens to change their lifestyle. Other economic and social aspects not mentioned in the plan at all prevent his idea from reaching the goal of being a realistically feasible study. In the end, while the plan is feasible under certain conditions, in a realistic test these conditions set forth to produce constant, steady and reliable power would just not be met. With some reevaluation and further in depth analysis of issues not mentioned by Jacobson, perhaps one day New York State and maybe even the whole country could run off of a wind, water, and solar system but more planning would be required to achieve this scenario.

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Appendix

Princeton Lighting Commission

Interviewers: Sean Callaghan

Interviewee: Brian Allen, Manager of Princeton Light Commission

Date and Time: December 4, 2013 at 12:30 PM

Where: Princeton Lighting Commission

Q: What was the total overall cost of the Project?

A: Seven million dollars initial cost with a variable maintenance and service cost per year up to $250,000.

Q: How does the power system work with the grid?

A: The power is generated by the wind turbines, then pass through a meter which passes it along to the grid. For each unit of energy put onto the grid, the town gains wind credits and has a deal for discounted energy with National Grid.

Q: Who is the power company that is involved in the windmill project?

A: National Grid provides the electricity for the area and thus controls the windmill portion of the grid.

Q: What was the issue that caused the failure of one of the turbines?

A: The gearbox was constructed wrong with improper size gears causing a total failure of the gearbox. Previously, a golf ball hitting one of the blades of a turbine caused a shutdown of the turbine that was struck until inspectors could be flown out to evaluate the damage.

Q: What is the predicted life cycle of the wind turbines?

A: The turbines have a lifespan of around 15 years however certain parts have a much shorter life expectancy. This includes the gearbox which is only predicted to last around seven years.

Q: What is the total cost of maintenance?

A: Maintenance costs vary from year to year but with the failures have reached a few hundred thousand dollars a year. In 2012, the total cost of maintenance was $800,000 with the total amount saved by installing the turbines being only $136,000. Without the failures however, this project could be making money fairly easily as the projected maintenance was only in the tens of thousands of dollars.

Q: What is the shut off speed for the wind turbines?

A: At 25 meters per second the blades become flat and the turbines turn away from the wind with a brake system engaging to prevent damage the wind turbines.

Q: Are the windmills meeting the expectations set forth by the project? Why or why not?

A: No, the windmills were not supposed to be as costly as they have become. All predictions were extremely off. The projected cost of electricity dropped as opposed to the prediction of an increase dashing the economic benefit of the turbines. The cost has raised, rather than dropped as predicted, the cost of power to 20 cents per kilowatt and caused the lighting's commission to spend 40% of its budget on the wind turbines alone. One of the largest issues in the community is the lack of industry preventing a large, continuous drain from the grid that would allow for the wind power generation to be used and beneficial to the town. Overall, the turbine cost has been so high that the town is trying to sell off the turbines at a 1.8 million dollar loss just to prevent having to pay for maintenance.

Hull

Interviewers: Sean Callaghan, John Goddard, Charles Mendes

Interviewee: Andrew Stern

Date and Time: December 6, 2013 at 4:00 PM

Where: Over the Phone, Worcester MA to Hull MA

Q: Where is Hull located?

A: Hull is located in Boston's outer harbor

Q: How many residents live in Hull?

A: 11,000 residents

Q: was the first time any renewable energy was used in Hull?

A: 1820's water pumped into vats to extract sea salt

Q: When and where was the first wind turbine/setup constructed in Hull?

A: 1984 smaller wind machine was installed at high school

Q: What type of machine was it and how many watts did it produce?

A: 42 Watt machine, lattice tower

Q: Did the machine have any extra storage for extra energy produced?

A: Machine had no extra storage for any extra energy produced

Q: How long did the first smaller machine at the high school run?

A: Smaller machine ran from 1984-1996

Q: How much money did the instillation of the machine save the school?

A: Estimate: saved school 90,000 dollars over 12 years

Q: Why did the use of the smaller high school machine cease?

A: It was not used anymore due to the fact that a Nor'easter in 1996 destroyed the machine.

Q: Who started and aided to the study to repower the old site of the machine?

A: Study done by the executive office of Environmental Affairs to repower site and UMass Amherst helped with study.

Q: How much was the offered kilowatt range with the new machine being proposed?

A: 100-250 kilowatt range offered for new machine

Q: How much was the wanted kilowatt range from the town and subsidiaries for the new machine?

A: 500-1 mega watt wanted for new machine

Q: Did the price that the town paid for the machine include every aspect of the machines upkeep, and construction or were those all separate costs?

A: Price that town paid for new machine included everything, upkeep, construction etc…

Q: When was the new machine constructed?

A: New machine was built on December 11th 2001

Q: How much was the cost of the new machine?

A: Cost 7,200 dollars

Q: How many watts per hour per year does the machine produce?

A: Produces 1,600 mega watt/hr per year

Q: How many years did it take for the machine to pay for its self if it has already?

A: In four years the machine paid for itself

Q: How was the tax credit, produced by the machine, used by the town?

A: The tax credit produced from the machine was is being used for newer after 2012

Q: What was the percentage of the town that supported wind after the construction of the new machine?

A: 95% wind support in town after machine was built and run

Q: When, if at all, did the town of Hull look for new place to construct more machines for wind power in the town?

A: 2002 new sites looked at to place more machines

Q: Where was the second machine installed?

A: Second machine was installed at closed land fill.

Q: Where there any complications/ difficulties in installing this second machine?

A: The one complication was that foundation needed to be driven down to support machine on the bedrock which made it a difficult installation

Q: What was the total cost of the second machine?

A: Total cost of second machine = 3.2 million dollars

Q: How much did the specialized foundation cost?

A: 750,000 dollars for foundation alone

Q: How much output did the new machine have?

A: Three times the output of the first machine which is about 4,500 mega watt production per year

Q: How much of Hulls energy requirement does this machine cover?

A: 11-12 percent of Hulls energy requirements

Q: Have other companies/groups shown interest in setting up other machines/renewable setups due to the success already in Hull?

A: Department of energy now has interest in building offshore wind turbines in Hull because of success

Q: What other renewables projects are the people of Hull supporting if any?

A: People of Hull are also pushing the Cape Wind Project on Nantucket

Mann's Orchards

Interviewers: Sean Callaghan and John Goddard

Interviewee: Bill Fitzgerald

Date & Time: October 19th 2012 at 2 PM

Where: Methuen Massachusetts

Q: What were the costs of the solar panels?

A: $987,000

Q: Is there a cost to winterize the panels?

A: No

Q: What is the return of the project?

A: $70,000-$125,000 in 10 years

Q: What is the brand effectiveness, and power output of the specific panel you are using?

A: Produces 220.4 kW a year on 760 panels

Q: What type of backup power do you have if the solar panels fail?

A: Return to grid power, or use a generator

Q: What hours of the day are they operational?

A: Around 8AM to 6 PM but it varies

Q: If the grid goes down do the energy from the solar panels work still?

A: If the grid goes down the solar panels stop working as well

Q: How do they work on cloudy days or during bad weather?

A: They still produce energy at a reduced amount.

Q: Did you have to get permits or licenses to get the solar panels?

A: One bit of advice if you want solar panels, get a lawyer. There is a lot of red tape, permits, and other things you need to do to get every moving forward.

Princeton Household

Interviewers: Charles Mendes & John Goddard

Interviewee: Dag Olsen

Date & Time: November 18th 2012 12 PM

Where: Princeton Massachusetts

Q: What were the costs of the solar panels?

A: $84,000

Q: Is there a cost to winterize the panels?

A: No

Q: What is the return of the project?

A: 6-7 years

Q: What is the brand effectiveness, and power output of the specific panel you are using?

A: 250 watt panels 24 panels on each tracker to make 12 kW

Q: What type of backup power do you have if the solar panels fail?

A: Generator

Q: What hours of the day are they operational?

A: 8AM-6PM but it is variable

Q: If the grid goes down do the energy from the solar panels work still?

A: No

Q: How do they work on cloudy days or during bad weather?

A: Yes but not as effectively

Q: Did you have to get permits or licenses to get the solar panels?

A: Yes

Hardwick Household

Interviewers: Charles Mendes & John Goddard

Interviewee: Tom Gaskill

Date & Time: February 2nd 2013 at 1 PM

Where: Hardwick Massachusetts

Q: Is there a cost to winterize the panels?

A: No

Q: What is the return of the project?

A: 10 years

Q: What is the brand effectiveness, and power output of the specific panel you are using?

A: 2640 watt peak power rating 2.1 kW a panel with 24 panels

Q: What type of backup power do you have if the solar panels fail?

A: wood stove and generator

Q: What hours of the day are they operational?

A: 8AM-6PM variable

Q: If the grid goes down do the energy from the solar panels work still?

A: No

Q: How do they work on cloudy days or during bad weather?

A: Lower productivity but still functional

Q: Did you have to get permits or licenses to get the solar panels?

A: Yes