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Case study: Feasibility analysis of renewable energy supply systems in a small grid connected resort

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ABSTRACT

Case Study Feasibility Analysis of Renewable Energy Supply

Systems in a Small Grid Connected Resort

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This paper presents a case study on the feasibility of a small grid connected resort in the marine west coast climate of Canada to implement a renewable energy supply system. The current industry conditions of three renewable energy systems are explored including small and large wind energy conversion systems, solar photovoltaic cell systems, and energy cell systems. Furthermore, these three systems are evaluated using the power load, wind, and solar radiation information from a specific resort. The renewable energy source assessment and optimization software HOMER (National Renewable Energy Laboratory, US) is used to evaluate the costs and benefits of each system. The software evaluates the payback period, the net present cost, and renewable factor of new systems to find the optimal system for the resort. The findings in the case study result in recommendations for the specific resort being tested as well as general recommendations for any small resort interested in implementing a renewable energy system. Furthermore, this paper will help guide small resort owners in simulating and testing, using the HOMER software, renewable energy systems specific to the needs of their resort.

Part I

Introduction

Volatile oil and energy markets have caused the price of electricity to be unstable which can be a problem for many small resort operators. Additionally, the threat of global warming and climate change as a result of CO^2 emissions has forced many people to become interested in renewable energy. This paper will explore the feasibility of electrical energy independence in small resorts, concentrating on the use of renewable energy sources including wind, solar, and energy cells. The information presented in this paper will be relevant for both new resorts and existing resorts that want to retrofit a new energy system in their current property.

The costs of both traditional and renewable energy sources and the effect of climate conditions on production rates will be examined. Average wind speed maps and how different average wind speeds change the energy output of wind turbines, therefore changes the cost of the energy produced will be explored. The solar index and its use to evaluate the cost of solar power by region will also be explored. This paper will then evaluate the cost of energy cells and traditional energy from the power grid to see which is cheapest. This information will be used in a case study about the Mackenzie Beach Resort on Vancouver Island in British Columbia, Canada. Using the power load, wind, and solar radiation information from the specific resort, the renewable energy source assessment and optimization software HOMER (National Renewable Energy Laboratory, US) will be used to evaluate the costs and benefits of each system.

Next, the results and findings of the HOMER software will be explained and recommendations will be made to the Mackenzie Beach Resort on the most feasible energy system for there climate conditions and energy use. Further general recommendations will be made to small resort owners on modeling and testing their own resorts for the most efficient renewable energy system using the HOMER software.

Purpose

There is little well known comprehensive information about the cost of renewable energy projects available to resort owners, so they have to research all types of projects in order to decide on the project that fits their resort best. This paper present the tools that resort should use to minimize the amount of time the research phase usually takes. This information will help small resort owners that are interested in achieving energy independence or implementing a renewable energy hybrid system to make decisions on the best way to accomplish it. The research will presented in a case study about a specific small resort. Furthermore, the information and recommendations presented in this paper should be easily adapted to other industries or personal applications.

Justification

It will be very helpful for small resorts to know if it is feasible for them to produce all or part of their electricity in an environmentally friendly way. The information presented in this paper will save both time and money for resort owners and eliminate duplicate research by resorts. If this paper can help just one hotel to be more friendly to the environment, then it has done a great deed. Furthermore, this research could easily be adapted to other buildings and businesses and has the potential to have an even bigger impact on environmental consciousness.

Constraints

The paper will purely be a cost analysis of energy independence and will not take into account any increase in business that may result from environmentally friendly initiatives. Tax incentives for green activities will also be ignored as they are different for every state in the United States and every country. Another factor that will be ignored is the cost of linking a new resort to a traditional grid as it will cost different amounts for every resort depending on their situation.

Further constraints come from the limited information that is available. The monthly average solar radiation will be used and the seasonally average wind speed will be used. More specific measurements would result in a more accurate study, but it is simply not available. Electricity usage at the Mackenzie Beach Resort is measured on a bimonthly basis. This data will be converted to average hourly use. More accurate electricity use data from the resort is not available, but would result in much more accurate models and recommendations. A recommendation is made for the resort to upgrade its power meters to allow the hourly data to be collected.

Part II

Introduction to the Literature Review

This literature review will explore previous literature on solar power, wind power, power cells, and the feasibility of renewable energy systems. The solar power section will look at the types of solar power, the current conditions of the solar industry, and how government policies are helping that industry. The wind power section will explain how wind energy is converted to electricity, look at the current industry conditions for wind power production, and explore the feasibility and possible future of wind energy. The power cell portion of the literature review will explain how power cells work and explore their costs and benefits. Lastly, the feasibility of renewable energy systems section will give a brief overview of previous case studies of renewable energy systems in the hospitality industry.

The Literature Review

Solar Power

The solar power industry has seen substantial growth over the past decade. This section of the paper is going to explain the four different types of solar power. The current market conditions of the solar industry will then be reported. Lastly, there have been many changes in government policy due to the new presidential administration in the United States. The changes that affect the solar industry will be highlighted and their effect will be explained.

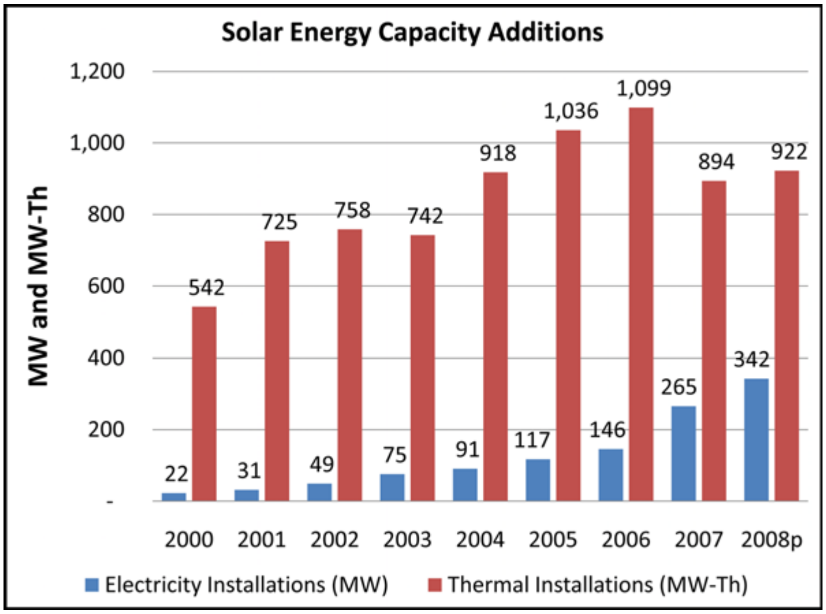
Types of Solar Power

When referring to solar power, we are actually referring to four different ways that the sun's power can be harnessed. The most common type of solar power is the photovoltaic cells that convert sun light to electricity. There are also heating and cooling systems that are powered by the sun; they are referred to as solar thermal systems. Concentrated solar power is the third type of solar power; it involves utility scale photovoltaic projects. The last type of solar power is lighting which involves saving electricity by installing skylights or windows based on the sun's position in the sky throughout the year (Solar Energy Industries Association, 2008).

Solar energy can also be broken into two types of systems, active and passive. Active solar systems convert the sun's heat and light into another form of energy. Passive solar power comes from special designs or building material that use the sun's position in the sky to provide direct heating or lighting. Passive solar projects also consider the need for shade on the building (Solar Energy Industries Association, 2008).

Current Solar Market Conditions

The U.S solar energy market has seen sustained increasing growth over the last 8 years in the photovoltaic market and industry observers expect that growth to continue even in the current tough economic environment. Total capacity of photovoltaics grew by 1,265 megawatts in 2008. This increased total capacity by a record high of 17 percent to 8,775 megawatts. The following figure shows a graph of the growth in the solar industry over the last eight years (Solar Energy Industries Association, 2008).



(Solar Energy Industries Association, 2008)

Figure 1. Graph of Solar Energy Capacity Additions

Photovoltaic (PV) cell production experienced a bottleneck at the beginning of 2008 with regard to the silicon needed to produce the PV. There was substantial investment in the production of the needed silicon which has eliminated the bottleneck, reduced the price of the silicon by 25%, and reduced the price of the PVs where 50 percent of their costs come from the modules created with the silicon (Solar Energy industries Association, 2008).

Solar thermal systems saw substantial growth in 2008. Fifty percent more solar water heating systems were sold in 2008 than in 2007. In 2008 alone, an estimated 139 megawatts thermal-equivalent (MWTh) of solar water heating systems were sold in 20,500 systems. The total amount of solar water heating megawatt savings is now 7636 MWTh. The market for solar water heating systems is very large with more than 80 million detached single-family homes in the United States. The removal of the solar investment tax credit cap should help to support the continuation of this growth in the solar thermal industry (Solar Energy industries Association, 2008).

Solar cooling systems are still relatively new. The technology is available to make them feasible but there is currently not enough suppliers to push down their price through economies of scale. This will change in the near future as more companies start supplying the market. There are currently a number of options of absorption coolers driven by hot water ranging in capacity. This makes it possible to develop solar cooling systems for most building sizes (Mateus & Oliveira, 2009). This portion of the solar thermal industry is expected to grow as the price of electricity, natural gas, and heating oil increase (Solar Energy industries Association, 2008).

Solar pool heating is the largest segment of the U.S. solar energy industry, even though sales have dropped slightly in both of the last two years. In 2008, systems equaling 762 MWTh were sold. These systems alone have an output of 12 billion BTU's or an 800-megawatt power plant. The decline in solar pool heating capacity growth in 2008 is thought to be caused by the downturn in the real estate market (Solar Energy industries Association, 2008).

Even though there were no concentrating power plants opened in 2008, projects totaling 6,000 MW have been initiated with signed purchase power agreements (Solar Energy industries Association, 2008).

The greatest challenge that the U.S. solar market faces is increasing production and distribution of solar energy to achieve economies of scale which will drive down prices to make solar energy more competitive with traditional fossil fuel sources. As more producers continue to join the industry and current industry members grow, economies of scale will be achieved (Solar Energy Industries Association, 2008).

Federal Government Policy

The end of 2008 proved to be very beneficial for the solar industry with regard government policy. The Emergency Economic Stabilization Act of 2008 (EESA) extended the solar Investment Tax Credit for eight years just three months before it would have expired. This tax credit allows individuals and companies to write off 30 percent of their investment in solar power against their taxes. Policies were changed so tax credits can now be credited against the alternative minimum tax. Another improvement in policy with regard to solar power is that utilities can now get an investment tax credit where it was prohibited before. The American Recovery and Reinvestment Act of early 2009 also had a beneficial effect on the solar industry by aggressively promoting investment in solar energy and removing the $2000 tax credit cap on residential photovoltaic systems, making them more affordable than ever. These policy changes will result in more stable demand which should allow the industry to continue to grow and prices to continue to fall. There were also some beneficial changes in state policy (Solar Energy industries Association, 2008).

A policy change that could have had a negative effect on the industry came from the Bureau of Land Management which placed a temporary freeze on applications to develop solar power projects on federal land. This freeze was lifted shortly after it was announced due to the actions by supporters of solar power and renewable energy advocates. The current economic downturn has also had a negative effect on the solar industry. Many companies have experienced problems when trying to get credit. Some major investors have decreased their investments in solar power. The downturn has also forced layoffs in some of the major solar companies (Solar Energy industries Association, 2008).

Wind Power

Wind power production has seen many advancements in technology and efficiency recently. This section will detail how wind power is converted to electricity. The current market conditions of the wind power industry will be explored. Next, the feasibility of different wind turbine technologies will be investigated. Lastly, potential future wind driven technologies and how they work will be explored.

How Wind Power is Harnessed

Wind has kinetic energy that is moving the air particles. This kinetic energy is converted to electricity through the use of a wind turbine. As the air particles fun into the windmill blade they are forced to rotate. As they rotate a shaft is turned. This shaft enters a gearbox to increase the speed at which the shaft is rotating. The output shaft that is spinning much faster than the input shaft is connected to a generator that converts the rotational movement into electricity at medium voltage. This medium voltage electricity is sent to a transformer where its voltage is increased, making it flow through power lines more efficiently. The electricity is then sent to a structure where it will be used. It can also be sent to a substation where the voltage is increased again to send it long distances or to battery where it can be stored for later use. Batteries are used on systems that are not connected to the utility grid. The electricity that is stored in a battery must then be sent to an inverter that modifies it to be compatible with home appliances. The batteries and inverter will increase the cost of this type of wind energy system (American Wind Energy Association, 2007).

Current Market

There is enough wind energy potential in the United States to power the entire country. North Dakota alone has enough wind energy potential to power a third of the country. However, currently less than 1% of the electricity consumed in the U.S. comes from wind power. Industry advocates feel that changes in regulatory barriers could help grow the industry. They believe that increasing the proportion of electricity provided by the wind to 20% is both affordable and feasible (American Wind Energy Association, 2007).

The wind energy industry saw substantial growth in 2008. One study says that sales of wind turbines will reach $11 billion in 2008, that is an increase of 42% from just one year earlier (Woody, 2008). It is expected that over 7,500 MW worth of wind power projects will be completed in 2008, bringing the total capacity to 21,000 MW (American Wind Energy Association, 2008). This saves about 32 billion tons of carbon dioxide production (Swisher, Real De Azua, & Clendenin, 2001). The following figure shows a graph of the growth in capacity of wind energy.

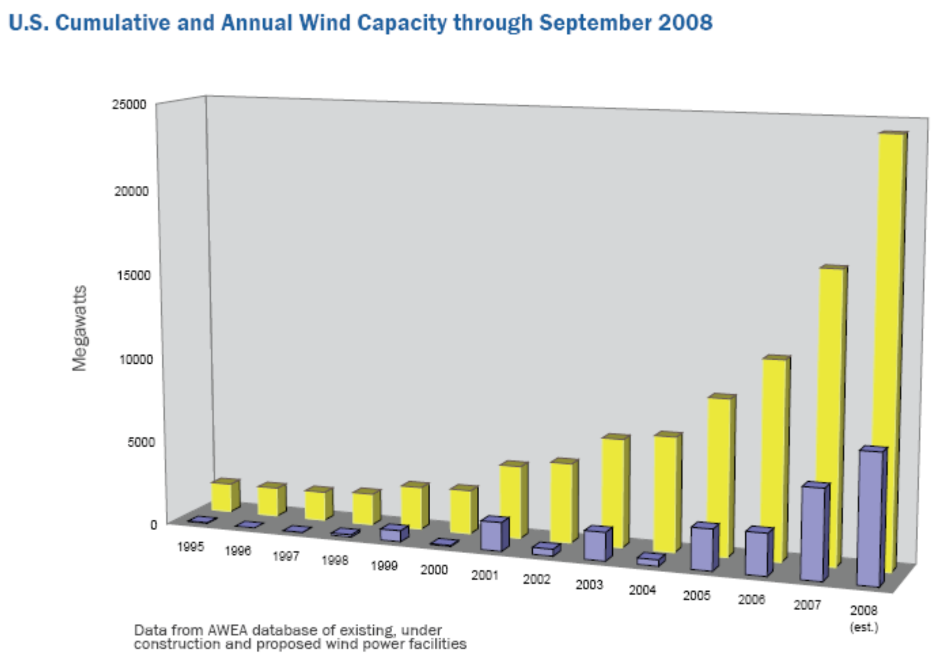


Figure 2. Graph of Cumulative and Annual Wind Capacity Growth

Feasibility of Wind Power

In the past 30 years the price of large scale wind energy projects has dropped more than 90%. This price drop is the result of technological innovations and is sufficient enough to allow wind energy to be produced at a competitive rate to energy produced in a new natural gas plant. There are five major technological changes that have helped to reduce the cost of wind energy. The increase in wind turbine size has been the most obvious change. In the early 90's, the average turbine size was 100kW. By 2001, that number had grown to 1 MW. Bigger turbines are more efficient. The weight of turbines have been reduced, this reduces the cost of the raw materials that are put into the project. Economies of scale have started to take effect and allow fixed costs to be spread over more products. Electronics and control systems have been improved to increase efficiency. Finally, turbine blade design has allowed the turbine to capture more of the wind energy (Swisher, Real De Azua, & Clendenin, 2001).

Other changes that have made wind power projects more feasible include the following. State policy leaders have increased the capacity of wind energy in their states. The cost of wind power has stayed stable when the cost of electricity from natural gas plants has gyrated sharply in the past. The cost of wind energy is very predictable because its fuel, the wind, is free. (Swisher, Real De Azua, & Clendenin, 2001). Forty-six states now have wind power production projects (American Wind Energy Association, 2007). The growth of competition in the electric industry and changes in their perceptions of the feasibility of wind plants has resulted in companies differentiating themselves with wind energy to attract customers that care about the environment. Now more than 190 utility companies provide wind based energy. The price of gas has risen in the past years, making wind energy more viable. Investing in wind power helps utilities to protect themselves from swings in the price of fuel. Lastly, tax credits from the government for environmentally friendly activities have moved many utility companies toward wind energy (Swisher, Real De Azua, & Clendenin, 2001).

Small wind turbines have also seen a steady drop in price, increased efficiency, and increased market share. These small wind turbines can be used for off grid projects, hybrid systems, and on-grid project. The prices of these systems can be competitive with diesel generators (Swisher, Real De Azua, & Clendenin, 2001).

The Future of Wind Energy

Entrepreneurs are increasingly looking for new ways to harness the power of the wind to save energy. This section of the paper will look at five ideas that may take off in the future. One company came up with the idea of attaching a giant paraglider shaped kite to ships. In a test run, the skysail was able to cut the cost of fuel by $1,000 a day. The company thinks its product can cut the cost of fuel by 10% to 35% per year. There are also environmental benefits of the product because it cuts gas emissions from the engine (Woody, 2008).

Another company is producing vertically mounted windmills. The blades are scoop shaped and can catch wind from any direction. The turbine is silent when operating and perfect for residential applications in low wind situations. The product comes in two configurations, a two-kilowatt and four-kilowatt, which is enough to power the average house. The payback period of this product is about ten years. Furthermore, new tax breaks for small windmills are now available from the Emergency Economic Stabilization Act of 2008 (EESA) which lowers the price and payback period even more (Woody, 2008).

The Magenn Air Rotor System (MARS) is a balloon filled with helium that is flown from 400 to 1000ft where there are steady winds. The balloon then starts to rotate and generates electricity that travels through its tether back to earth. The MARS can be deflated at any time and moved to new locations off the grid. Each system produces enough kilowatts to power the average house (Woody, 2008).

Researchers at Delft University have come up with another idea to harness the winds energy. They call it a Laddermill. It is a series of kites that are tied together and fly up to five miles high where they then return toward earth in an endless loop. As they fly, they pull ropes that are connected to generators on the ground. The researchers say the system can produce 100 megawatts of electricity or enough to power 100,000 homes (Woody, 2008).

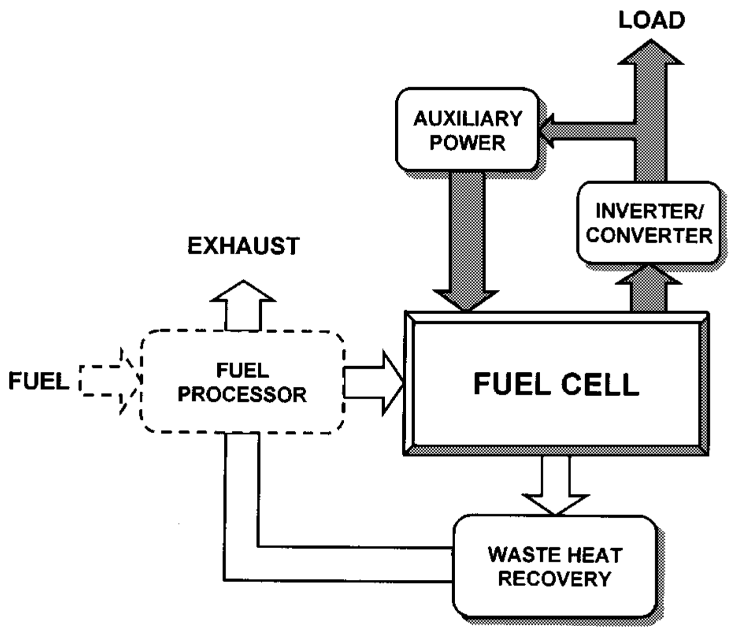
The last wind concept that will be discussed is a combinations between solar and wind power. The startup Cool Earth is increasing the efficiency of solar photovoltaic cells by putting them in an air filled balloon that focuses the sunlight on the chip. The key to this product is capturing the power of the air. The balloon is about 20 pounds, is made from the same material as a chip bag and costs about $2 to produce. The company uses air pressure to change the shape of the balloon to constantly focus sun rays on a highly efficient photovoltaic cell. This increases the electricity production by the cell up to 400 times. Two of these balloons would power the average house (Woody, 2008).

Fuel Cells

Fuel Cells are very clean and safe, and can be used for both thermal energy and electricity productions. However, fuel cells can be very costly. This section of the literature review is going to explain how fuel cells work and explore their costs and benefits.

How They Work

Fuel cells convert the energy from chemical reaction to electricity and thermal energy. The fuel cell consists of two electrodes and an electrolyte. Hydrogen, the usual fuel, is supplied to the anode where it is oxidized and gives off electrons. The electrons travel through an external circuit to the cathode where they are consumed to reduce the oxidant. Ions are traveling through the electrolyte at the same time to balance the flow of electrons and completing the electrical circuit (Ellis, Von Spakovsky, & Nelson, 2001; Farooque & Maru, 2001). A diagram of a basic fuel cell is presented in the following figure.



(Farooque & Maru, 2001)

Figure 3. Diagram of the Basic Fuel Cell

Fuel cells are efficient at part and full capacity and come in a variety of sizes. They can be used for a wide range of activities including powering portable electronics, transportation, building cogeneration, and being used as a utility power plant. In both portable and transportation uses a fuel cell is combined with a fuel container that can have very high energy storage density. In transportation functions, fuel cells have been shown to be much more efficient and better for the environment than internal combustion engines. Building cogeneration is accomplished when a fuel cell system is used for electricity and thermal heat.

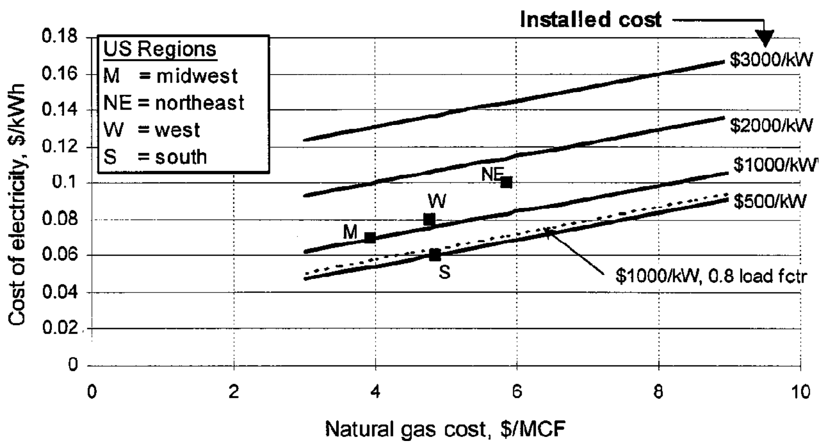
This type of system can be used in high density areas because there are very low emissions and has been found to be 80% efficient (Ellis, Von Spakovsky, & Nelson, 2001).

Benefits of Fuel Cells

The biggest benefits of fuel cell generators are that they are highly efficient and extremely clean. They can also be used to provide heat and power to a building. The cleanliness of fuel cells and the fact that they have produce little to no pollution allows for a reduction in government regulation. Fuels cell projects usually gain regulatory approval easily. Fuel cells also have very few moving parts so they are very reliable, quiet, and require very little maintenance. As mentioned before, fuel cells are efficient no matter the size. This means they can be located at the site where the power is needed and scaled to reduce costs (Farooque & Maru, 2001).

Cost of Fuel Cells

Fuel cells have a maintenance cost of between $0.01 to $0.03 per kWh. Consumers can buy a 200 kilowatt equivalent (kWe) system including installation for about $5,000 to $5,600 per kWe. As the technology used to produce fuel cells improves and production volumes increase, costs of fuel cells are expected to fall to $1,000 per kWe or even lower. If the cost of fuel cells falls below $1,000 per kWe, then they will be competitive with conventional power generating systems. If the price falls even lower, they will surely become a dominate provider of building electricity and heating. The figure below shows the relationship between the cost of fuel cell systems compared to the cost of electricity and gas (Ellis, Von Spakovsky, & Nelson, 2001).



Assumptions:

Electrical load factor:	0.5 (except where noted)
Thermal/electric ratio	0.5
Thermal use factor:	0.3
Efficiency of alternate heat source:	0.8
Electrical conversion efficiency:	0.4
Thermal output fraction:	0.4
System maintenance cost:	$0.01/kWh
Expected system life:	20 years
Rate of return:	12 percent

(Ellis, Von Spakovsky, & Nelson, 2001)

Figure 4. Graph of Fuel Cell Efficiency compared to Electricity and Gas Costs

Feasibility of Energy Independence

When looking at the feasibility of a stand-alone or grid connected hybrid electricity system that includes a renewable energy source, it is important to consider reliability and cost. Studies have shown that hybrid systems are usually more reliable and cheaper than systems with only one source of electricity. It is also important to take climate into account when designing a system. For example sunny places will be more ideal for photovoltaic hybrid system than will be places with constant cloud cover (Bernal-Agustin & Dufo-Lopez, 2009).

Previous Studies

This section of the paper will examine three different feasibility studies of renewable energy systems in the hotel industry. All of the studies use the software HOMER to model and evaluate the feasibility of each system. HOMER can be downloaded for free at https://analysis.nrel.gov/homer. One study looks a grid connected large hotel, another looks at a stand-alone renewable energy system for a large hotel, and one study looks at small to medium tourist accommodations with stand-alone power supplies (Dalton, Lockington, & Baldock, Case study feasibility analysis of renewable energy supply options for small to medium-sized tourist accommodations, 2009; Dalton, Lockington, & Baldock, Feasibility analysis of renewable energy supply options for a grid-connected large hotel, 2009; Dalton, Lockington, & Baldock, Feasibility analysis of stand-alone renewable energy supply options for a large hotel, 2008).

A large hotel is classified as one with 100 or more beds. In the study of optimizing energy production in a grid connected hotel, the renewable factor, net present cost (NPC), and payback period were evaluated. The renewable factor (RF) is the percent of energy that comes from a renewable source. It was found that the NPC of a hybrid grid/renewable energy source (RES) was comparable to the grid–only supply and had an RF of 73% and a payback time of 14 years. The hybrid system also reduced greenhouse emissions by 65 percent. It was also found that the RES only system could supply 100% of the electricity but was not economical. Further examination of the model shows that large scale (> 1000 kW) wind energy conversion systems (WECS), are more economical than photovoltaic cells and multiple small-scale WECS (0.1 – 100 kW). Not taken into account on this model is the possible increase in grid supplied electrical costs and the imposition of carbon taxes, which would have a greater negative impact on grid only systems. Findings indicate that in the situation tested, the hybrid system described above is indeed more economical over a 20 year life than is the grid only system. The NPC of the hybrid system is 50% lower than the grid only system (Dalton, Lockington, & Baldock, Feasibility analysis of renewable energy supply options for a grid-connected large hotel, 2009).

In the study of a stand-alone renewable energy supply for large hotels, it was found that RES systems can produce 100% of the energy required to sustain the property. However, the lowest NPC comes from a RES/diesel hybrid system with an RF of 76%. Compared to a diesel generator-only configuration, the NPC of the project is reduced by 50% and the greenhouse gas emissions are reduced by 65% with the hybrid system. The hybrid scenario also results in a payback period of 4.3 years. Similar to the grid connected hotel study, it is found that large-scale WECS are more efficient than photovoltaic cells or small-scale WECS. It is important to note that these studies are specific to their locations and not universally applicable for all hotels (Dalton, Lockington, & Baldock, Feasibility analysis of stand-alone renewable energy supply options for a large hotel, 2008).

The third study looks at the feasibility of renewable energy supply (RES) systems for small to medium-scale hotels with less than 100 beds. The properties are also dependent on stand-alone supplies. Once again the optimization test was based on payback period, net present cost (NPC), and renewable factor (RF). Three different properties with hybrid systems already utilized were evaluated. Additionally, all the properties were located in different climates with different geographic characteristics. It was found that RES only systems can produce enough electricity reliably, but it is more economical to use a hybrid system. In the majority of cases, the best strategy to reduce NPC was to add further RES to the system, resulting in a better RF factor and shorter payback times. It was also found that the optimized RES/hybrid systems were comparable to a diesel generator only system. Furthermore, it was found in the examined cases that wind energy conversion systems (WECS) were more economical than photovoltaic cells. There was an increase of about three years in the payback period from 3.5 years to 6.5 years when photovoltaic cells were used. Fuel cells were also tested and it was found that they were not economical. When an increase in diesel fuel costs and the implementation of a carbon tax were modeled into the experiment, the RES/hybrid configuration became even better of an option at each property (Dalton, Lockington, & Baldock, Case study feasibility analysis of renewable energy supply options for small to medium-sized tourist accommodations, 2009).

Part III

Introduction

This portion of the paper is going to present a case study of the feasibility of a renewable energy system in a specific small resort on Vancouver Island in British Colombia, Canada. Electricity system simulation and optimization software is used to evaluate different electricity systems. The results of the simulation and optimization software will then be discussed and conclusions and recommendations will be made for the resort about the best type of system to install. General recommendations will also be made to other small resort owners about how to test renewable energy systems in their resorts.

The Resort

This case study is about the feasibility of electrical energy independence for the Mackenzie Beach Resort, located on Mackenzie Beach in Tofino, British Colombia, Canada. Mackenzie Beach Resort is the oldest, year round resort in Tofino and has been family owned and operated since it began in the early 1970's. Early tourists, eager to reach the ocean, were only permitted to use the logging road on the weekends when loggers had days off. From this Tofino's tourism industry began to grow. That same road, paved since 1972, is Canada's only paved road to the open Pacific Ocean with Tofino marking the official western terminus of the Trans Canada Highway.

Nearly 40 years ago a man named Bob Mackenzie acquired the stretch of coastline and all the land between the water and highway. He named it Mackenzie Beach. He also purchased an abandoned building next to the runway at Tofino Airport that had been used as pilot housing during World War II, placed it on a barge and towed it around the tip of Tofino to where it sits today as Cabin #1 at the resort. The Mackenzie family lived in this cabin while building their family home, the resort front office and residence, from wood and other fittings that washed up on the beach after falling off cargo ships further out in the pacific. Mackenzie Beach Resort is currently owned by Dorothy and Mirko Lescanec and has resident managers, Sam and Krysta, who are responsible for the daily operations of the property.

Mackenzie Beach Resort strives to be environmentally friendly. Even though all of its electricity comes from the grid, the management has implemented other programs to benefit the environment. The resort pool uses salt to sterilize the water instead of harmful chemicals.

All of the light bulbs on the entire property have been replaced with compact florescent light bulbs which are more efficient and last longer. The fire wood that is supplied to the cabins only comes from second growth forests. Instead of using thousands of small shampoo and conditioner bottle, these shower gels are dispensed out of pumps in each shower. Finally, they have implemented an extensive recycling program where the resort and guests can recycle many of their used products instead of just throwing them in the garbage.

The resort is classified as a small resort; it currently consists of 14 cabins of various sizes, 18 RV sites with hook-ups and power, 43 tent sites, a pool and hot tub, and a front office with attached manager residence. The cabins have a total maximum capacity of 70 guests and contain 40 beds. Each cabin has a full kitchen and two sources of heat. The main heat source in each cabin is electric baseboard heaters, but each cabin has a wood burning fireplace with the exception of cabins 11 through 14 which have gas fireplaces. The year is broken up into four different seasons for the resort. Below is a table of the dates of each season.

Table 1. Mackenzie Beach Resort Seasons

Low Season	**Mid Season**	**High Season**	**Holiday Season**
Jan 2 to Mar 12 Oct 13 to Nov 6 Nov 10 to Dec 19	Mar 13 to May 15 May 19 to Jun 26 Sept 2 to Oct 9 Dec 19 to Dec 31	Jun 27 to Sept 1	April 10, 11, 12, (Easter) May 16, 17, 18 (Victoria Day) Oct 10, 11, 12 (Thanksgiving) Nov 7, 8, 9 (Remembrance Day)

One of the main uses of electricity at this resort is for heating. The temperature correlates with the occupancy of the resort in that the low season is when it is cold outside and high season is in the summer when it is warmer. This correlation results in relatively even energy consumption from month to month even thought the number of guests vary. In the low season there are few guests, but they use a lot of electricity to heat the cabins. While in the high season, there are more guests but they do not need to use as much electricity to heat the cabins.

Mackenzie Beach Resort is connected to a traditional grid and consumes around 320,000 KWh of electricity per year that it purchases from the local utility company, BC Hydro, for $0.084 per KWh. This results in a yearly electricity bill of $27,840.97. They receive a power bill every two months. The property contains 16 power meters; the information from each power meter is combined to equal the total power usage of the entire resort. The electricity consumption information used to model a new electricity system came from these electricity bills.

The climate the resort is located in is the marine or humid west coast climate. This climate is found on the west coast of mid latitude continents and is very humid through most of the year. Its geographic location results in westerly winds from the ocean that bring cloudy skies, mild temperatures, and a lot of precipitation. The climate is greatly influenced by the orientation of the mountain systems in Europe and North America.

The winds generated in this climate are usually mild and has a yearly average speed of 5.09 meters per second. Furthermore, the solar energy production opportunities are also low because of the cloudy skies. The average daily radiation in Tofino is only 3.290 kilowatt hours per meter squared per day. This climate creates relatively little power production potential for either wind turbines or solar panels.

Methodology

In the methodology section of this paper, the data input sources will be explored and evaluated. These data inputs include the electrical use data of the Mackenzie Beach Resort, the solar radiation and wind speed information for the area of the country where Mackenzie Beach Resort is located, the cost and efficiency of different solar panels and wind turbines, and the cost and buyback rate of electricity from the utility grid. The method and criteria that the HOMER software uses to test the feasibility of different electrical system will also be explained. Lastly, the results of the optimization test run by the software will be examined and explained.

Data Inputs

The electricity use data inputs for the HOMER software came from the bimonthly electricity bills the resort received. The average electricity use for each month was then split evenly to form daily electricity consumption for the resort. These daily electricity consumption amounts were then split evenly again to form the hourly consumption of the resort. The model would have been much more accurate if true hourly electrical data from the resort was used instead of estimates, but that information has not been collected. To make this a more accurate study, the resort would need to monitor its hourly electricity consumption for an entire year and import that data into the HOMER software.

The monthly solar radiation information was imported from the National Renewable Energy Laboratory website (U.S. Department of Energy, 2009) automatically by the HOMER software. Actual daily measurements would have been more accurate, but that information is not available, so the monthly average was used. It is found that the average solar radiation for the year is 3.29 kilowatt hours per meter squared per day with a summer peak of 5.98 kWh/m^2/day in July and a winter low of .8 kWh/m^2/day in December. Below is a graph of the yearly solar radiations measurements.

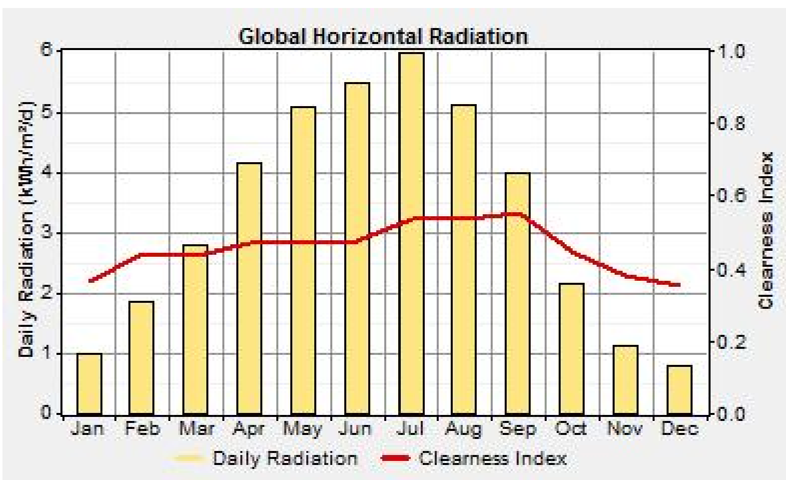


Figure 5. Graph of Average Monthly Solar Radiation

The average wind speed information was obtained from the wind atlas website (Environment Canada, 2008). The measurement of the wind was taken in Tofino, BC, Canada which is about 2 km from the resort. It was found that the yearly average wind speed is 4.85 meters per second(m/s) with a low of 3.16 m/s in the summer and a high of 7.20 m/s in the winter. The wind speed information was only available by season. The model would be more accurate if daily average wind speed information was available and used. Below is a graph of the wind data that was used for the model.

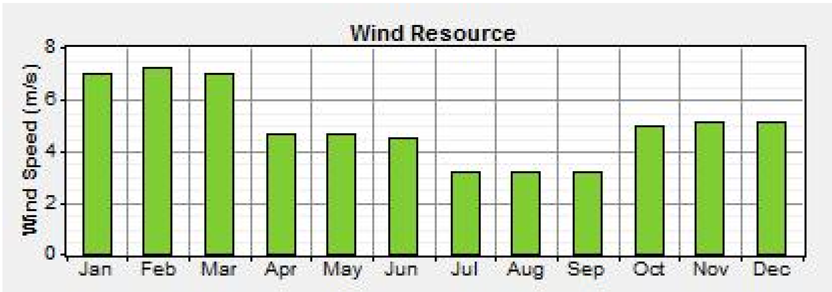


Figure 6. Graph of Monthly Average Wind Speed

Wind turbine wind energy conversion rates were provided by the HOMER software. The price for each wind turbine was found on the manufactures' websites. Three different wind turbine configurations were tested. The first was a single large GE 1500 kW rated wind turbine with a cost of about $2.5 million with installation. The second system included many small 5 kW rated vertical axis wind turbines manufactured my Enviro Energies with a setup cost of $30,000 per turbine. There are a number of different sail sized that can be installed on these turbines. Large sails are better for low wind applications. Since the average wind speed is relatively low at the location of the resort, the largest sail configuration where tested. The larger sail also costs $9000 more than the small sails. The third system was a 50 kW capacity turbine by AOC with a cost of $150,000. All of the initial costs include installation. It was also assumed that the lifetime of each wind turbine is 25 years.

There were three different Photovoltaic solar cells tested as well. All three cells are manufactured by Sanyo, a leader in the solar power industry. The first was a 3 kW system with an initial cost of $14,000. A 5.5 kW rated panel was also tested with a cost of $24,000. Finally, an 8 kW rated panel was tested with an initial cost of $45,000. All of the pricing for the solar panels came from the manufacturer's website.

A converter is needed to convert the DC electricity that is produced by the solar panel and Enviro Energies Wind Turbins. The cost of this continuous 6 kW DC to AC converter is $5000. It is only required when a solar panel or the Enviro Energies wind turbine is used.

Batteries were not needed in this system because power can be sold back onto the grid at a better rate than it would cost to store it for later use in a battery. The buyback rate the utility company, BC Hydro, gives to its customers is $0.054 per kWh.

All of the information about the cost of grid electricity was taken from the recent power bills the resort received. It was found they are paying $0.084 per kWh of electricity. The energy flow diagram for the alternating current (AC) and direct current (DC) buses used in the simulation of new energy systems at the Mackenzie Beach Resort can be found below.

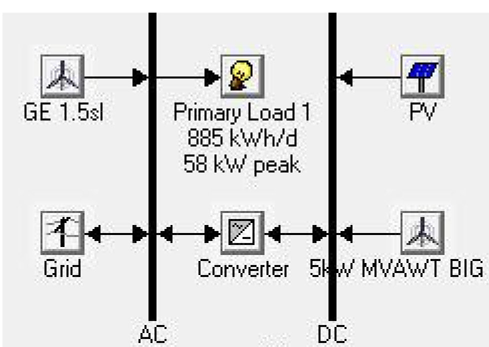


Figure 7. Energy Flow Diagram for Mackenzie Beach Model

Testing

The software HOMER was used to simulate the different energy systems available to the resort. It then finds the optimal system based on the net present cost, renewable factor, and the payback period. The net present cost is the present value of all setup and maintenance costs over the life of the project. It is calculated by using the following equation.

$$NPC(\$) = \frac{TAC}{CRF}$$

Figure 8. Net Present Cost Equation

In the above equation, TAC is the total annualized cost of the system and the capital recovery factor (CRF) is calculated using this equation

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1}$$

Figure 9. Capital Recovery Factor Equation

In this equation, N is the number of years the project is expected to last and i is the annual real interest rate. The real interest rate is used so that all costs are calculated in constant dollars.

The HOMER software also takes into account the salvage value of the equipment at the end of its useful life. This is the value that the component parts should be able to sell for when the project is disassembled and replaced. The salvage value is calculated using the following equation.

$$S(\$) = Crep\frac{Rrem}{Rcomp}$$

Figure 10. Salvage Value Equation

Crep is the replacement costs of each component, Rrem is the remaining life of the component, and Rcomp is the entire life of the component.

The renewable factor is the amount of energy consumed that comes from a renewable source. It is calculated simply by dividing the amount of electricity produced by renewable sources by the total energy consumption of the property.

Finally, the payback period is calculated using grid only costs and grid – renewable energy source (RES) hybrid system costs. The present value of the annual savings of the hybrid system over the grid only setup are then calculated and summed to offset the initial construction costs. The year that the sum of the present value of annual savings is greater than the initial construction cost is the payback period.

Results

When the optimization test was run on all the data that was entered into the HOMER software, it was found that the most cost effective energy system is the grid connected system with no renewable sources of electricity. This is the present configuration of the resort. The grid only configuration monthly payments are the basis for which other systems' payback periods are evaluated. Since there are little to no savings every month with hybrid systems, there is no payback period for any of them. Furthermore, the overall cost per kilowatt of electricity is lowest in the grid only configuration by $0.02. The electricity is all coming from the grid which results in a renewable factor of zero. Lastly, the net present cost (NPC) of the future electricity bills is $382,431 which is the lowest of any of the other system configurations.

The next best setup if renewable electricity is used is a hybrid grid/solar system. The solar system that would be used is the 3 kW rated system which is the smallest system. The initial costs for this system would be $15,000. The savings per a year that would result from this system is only $74. This means that there is no payback period for this system because the savings will never offset the initial costs. This system results in a very small renewable factor of 01. That means that only 1 percent of the electricity used by the resort would come from a renewable source. The NPC of this system is $396,377 which is $13,946 more than the grid only system.

The third best system configuration is a hybrid grid/small wind turbine system that is rated at 5 kilowatts. This system would have an initial setup cost of $31,000 and result in only $653 in electrical savings per year. Similar to the hybrid grid/solar system, this system will never pay for itself. The renewable factor for this system is .06 which means only 6 percent of the electricity used by the resort is going to come from the Enviro Energies wind turbine. The NPC on this system is even higher than the grid/solar hybrid system. It is $404.223 which is $21,792 more than the grid only system.

The least expensive system that incorporated both wind power and solar power with the grid electricity is one were a 3 kW solar system is used along with a single 5 kW wind turbine from Enviro Energies. This system results in yearly savings of $755 but has a setup cost of $45,000. As with the past two hybrid system, this system also will never pay for itself, but it results in the highest renewable factor of any of the previous systems at .07. The NPC of this system is also very high at $416,786 which is $34,355 greater than the grid only system.

The resort is too small to sustain a large wind turbine, the most efficient system using a large turbine has a renewable factor of .94, but the NPC is very high at $1,232,837. The yearly savings to the resort would be $117,043 because they could sell the excess power they generate back to the utility company, but that is still not enough to pay off the initial investment of $2.5 million.

Conclusion

The feasibility of renewable energy systems was tested on a grid connected resorts in the marine west coast climate. Three factors were considered to determine if it was feasible for a small resort to implement a renew energy system. These three factors were the payback period, the renewable factor, and the net present cost. In all three hybrid grid/renewable source systems the payback period was nonexistent. That is to say the present value of the energy cost savings never equaled the initial cost of the renewable energy source. The renewable factor in each of the most efficient hybrid systems was very low, less than 10 percent. This can be attributed to the fact that regardless of the size of the system, over its entire lifetime, the cost per kW of electricity is greater than the cost of a kW of electricity from the grid. This means the program found the system configuration with the lowest initial setup cost and added it to the model to make the hybrid system that was the least expensive. The program knew the price of any hybrid system would never be made up from the savings in electricity costs. Every hybrid system also had higher net present costs than the grid only system. The reason for this is the savings from the system never offset the cost of the system.

Previous cases have found that hybrid energy systems are feasible in large grid connected hotels, large energy independent hotels, and small and medium hotels that are energy independent. In these cases the hotel could produce electricity at a cheaper rate than the utility company or the costs to connect to the grid was high and offset the costs of renewable systems. Previous cases have also had better climate conditions for producing electricity. In this case the climate conditions do not allow for the efficient production of renewable energy. It is very important to note that this case is specific to the climate conditions of the resort, so it cannot be applied to every small grid connected resort.

From this case, it can be concluded that it is not feasible for a small resort, similar to the Mackenzie beach resort, already connected to the grid in the marine or humid west coast climate to produce its own electricity. This climate is not conducive to either wind or solar energy production. The average wind speeds are too low to allow a wind turbine to produce electricity at a cost that is that is lower than the cost of energy from the grid. Furthermore, the solar radiation in this climate is very low. Solar panels with as little sun as is present in the marine west coast climate are not very efficient. It is not possible to produce electricity from solar panels at a lower cost than energy from the grid.

Another factor that results in renewable energy systems not being feasible is the low cost of electricity in the region where the resort is located. The total cost of electricity per kW for the resort is only $0.084 which is close to the lowest for the entire country of Canada. If the cost of electricity was to double to $0.168, then it becomes feasible for the resort to install a single large windmill or a few medium sized windmills. The price of $0.168 per kilowatt is already being paid in some regions in Canada, including Charlottetown on Prince Edward Island. If the price of electricity and buyback rate that the utility pays for excess electricity were to both double, it becomes very feasible for the resort to build a single large wind turbine. The net present cost of such turbine would be -$732,264. The payback period for this turbine is 11.98 years. Furthermore, the renewable factor is very high at .94. Even though the initial costs of the turbine is $2.5 million. The company would save $52,977 dollars a year and earn $229,337 from selling electricity back to the utility company. This results in a net benefit of $282,314 per year for the resort. Solar panels are still not feasible even if the price of electricity were to double.

In cases where a new resort is planned, it is important to consider the costs of connecting to the grid. These initial costs to connect to the grid that the resort would have to pay may be enough to offset the cost of renewable energy systems and make them feasible even in the marine west coast climate.

Recommendations

From the research preformed and the tests run in this case study, recommendation can be made to the Mackenzie Beach Resort to not invest in a renewable energy system yet. The current economic and environmental conditions are more favorable to buying energy from the local utility company. There are no configurations of a renewable energy hybrid system that would result in a lower net present cost of electricity for the resort.

More importantly, it can be recommended to the resort to continue to monitor the economic environment of electricity. If electricity prices are to rise or the prices of renewable systems are to fall, that data needs to be factored into the modeling software to reevaluate the feasibility of a renewable energy system.

Recommendations are also made to the resort to better monitor its electricity use. The model would be much more accurate if hourly electricity use data was available from the entire resort for an entire year. If possible, the resort should install updated electricity meters with the capability of recording hourly use data. This is the most accurate and easiest way for the resort to collect its detailed electricity use data. The resort should also collect hourly wind speed data in its specific location. There is currently only seasonal wind speed information available which results in a less accurate model in the HOMER software. These more accurate data samples will result in a much more accurate model in the HOMER software to determine the feasibility of a renewable system.

Furthermore, the recommendation is made to any resort that is considering a renewable energy system to use the same software that was used in this case study to model the electricity system at the Mackenzie Beach Resort. The HOMER software is free to download at https://analysis.nrel.gov/homer/ and has been found to be very accurate when accurate data is used to model the new energy system. The software is a great way to find the optimal energy system for the project being modeled. It is also important to note that each system needs to be modeled to determine if it is feasible. There are many inputs, specific to each project, that affect the feasibility and efficiency of a renewable energy system. It is not possible to generalize results from one study to an entire industry.

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