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Wind and Solar Energy Projects at the EcoTarium

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Wind and Solar Energy Projects at the EcoTarium

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

by
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Date:
15 December 2010

Report Submitted to:

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Abstract

Through their upcoming solar and wind energy projects, the EcoTarium, a science and discovery center in Worcester, Massachusetts, seeks to help people overcome their uncertainties towards renewable energy. Therefore, the goal of this project was to aid the EcoTarium in the design stages of their wind and solar energy exhibitions. Through these exhibitions, the EcoTarium hopes to promote the understanding, accepting, and adopting of renewable technologies in the Worcester community and beyond and help contribute to a clean energy future.

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Rajib Mallick

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The EcoTarium Staff

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Authorship

This Interactive Qualifying Project represents the equal contribution of all members of the EcoTarium project team.

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Executive Summary

The EcoTarium, a science and discovery museum in Worcester, Massachusetts, seeks to prompt the public's adoption of renewable energy through the installation of a wind turbine, a solar panel array, and the associated educational exhibits. In order for consumers to understand, accept, and adopt renewable energy, they must first overcome their uncertainties regarding the technology. According to California Energy Commission, the hurdles for investing in renewable energy systems include (Cronk & Esternon, 2002):

- High initial investment, with an unclear return on investment
- Lack of knowledge regarding the equipment, its technological application, and availability
- Perception that the installation processing is difficult and complicated
- Lack of trusted references from (friends, neighbors, etc.) that have installed their own solar or wind systems
- Difficulty in finding a qualified installer

Therefore, any renewable energy exhibit developed by the EcoTarium must address these factors in order to subsequently address the renewable energy adoption issue.

The goal of this project was to aid the EcoTarium in the preliminary design stages of their wind project and more extensive stages of their solar energy project. We provided useful recommendations, enabling them to move forward with the design of these proposed installations. In order to do this we:

- Provided the EcoTarium with preliminary ideas for use in future solar exhibits
- Began the work for a solar panel installation
- Conducted the preliminary steps of a wind study
- Made suggestions for a future wind turbine installation

The exhibit concepts we proposed will provide guests with interactive, engaging, informal education regarding solar energy and its applications. All the while, these concepts will encourage the acceptance and adoption of the solar technology.

A Solar Exhibit Must Alleviate Consumer Uncertainties

As mentioned above, any renewable energy exhibit developed by the EcoTarium must address consumer uncertainties in order to subsequently address the renewable energy adoption issue. These exhibits are designed to help people understand renewable energy technology with the hopes of helping them accept and adopt it. We conducted research and interviews to get a better idea of the exhibit design process as well as to garner ideas for an effective renewable energy exhibit. We also pooled our own ideas together to create designs that adhere to a set of criteria intended for creating successful family exhibits.

Two major components exist for conveying information about solar technology. One of these components is displaying information about the system installed; the other is creating an exhibit(s) to teach solar concepts for both children and adults. This is a crucial point because adults will be interested in the monetary and energy savings associated with the technology, while children may find the concepts interesting. Striking a balance between these two age groups will be essential to an appropriate exhibit design. By informing adult guests of what solar energy can do for them, and teaching children why we need solar energy, an exhibit can promote the future use of the technology. Also striking the balance between information and fun will be important to helping people adopt renewable energy since people often remember more of what they do and have fun with than simply being lectured (Veverka, 1998, pg25).

In order to alleviate the various consumer uncertainties, each will have to be addressed in one way or another. The investment cost and return on investment can be addressed through such things as interactive displays which can convert the energy output of a panel array into monetary savings. This can be done through some manner of chart or graph that changes based upon the output of the panels. If people can see the savings they may be more willing to consider an installation and get over the initial investment cost.

Addressing the lack of knowledge regarding the equipment, its technological application, and availability is fairly simple. The byproduct of installing a working solar array allows the EcoTarium to better inform people what types of systems they could install on their own homes and provides guest with a greater understanding of what is available. An exhibit that engages people and is interactive can inform people about the concepts of solar energy and how they are applied to a working system as well. Just being able to see a system up close and get an idea of what it consists of may greatly increase understanding and acceptance of the technology.

Another byproduct of installing a working system on-site will be the ability to address the perception that the installation processing is difficult and complicated and the difficulty in finding a qualified installer. A simple way to address this issue is through a time lapse video of the installation process of the EcoTarium's own system. This will allow people to see how a system is installed and by whom it was installed. The firsthand experience with a solar contractor will aid the EcoTarium in determining how to help other people find a reputable installer.

One of the biggest ways that the EcoTarium can help people though exhibit design is addressing the lack of a trusted friend or neighbor who has installed a system. By having their own system and going through the entire installation process, the EcoTarium can be that trusted friend or neighbor that people may need. Many guests are repeat visitors and have come to know the EcoTarium as a family-friendly learning center. This is a credit to their organization and will help them guide guests to renewable energy.

By implementing solar energy concepts and information though interactive, engaging, and family friendly exhibits, the EcoTarium will be able to help counter consumer uncertainties and promote the understanding, accepting, and adopting of renewable energy. Based upon some of our proposed exhibit concepts, the EcoTarium will now have a starting point for their own exhibit design process. Incorporating these concepts and exhibit ideas in conjunction with a working solar array, will undoubtedly yield the best results.

The EcoTarium Must Install a Residential-Sized Solar Array

In order to relate to the most guests with any of the concepts mentioned above, the best type of system for the EcoTarium to install is a 2-4 kilowatt photovoltaic (PV) array. We came to this decision based upon our initial discussions with the EcoTarium staff, our research, and proposals from renewable energy contractors. Each of these steps played an important role in determining the best system options and each are outlined below.

The purpose of a solar installation was to present solar energy to the public and help them understand, accept, and adopt it. Initially, both solar water heating and solar photovoltaics were discussed as possible options for the EcoTarium's Apple Spice Junction, a small outbuilding on the center's grounds which contains restrooms and a snack bar (see Figure i). From our discussions with the EcoTarium staff, their desire to power the entire outbuilding or supply all of its hot water became clear. The idea of supplying all of the building's energy needs with solar energy stemmed from the notion that showing

Figure i: Front view of the Apple Spice Junction people a concrete example of a solar installation would help people overcome their uncertainties with renewable energy.

In order to see what systems were possible, we conducted our own research on the Apple Spice Junction building and its usage, power consumption, and how it was tied into the main building. We found that the building is tied into the EcoTarium's local grid, drawing power form the main building and the sites independent power plant. We also discovered that the building is not used all year, due to museum attendance and winter weather. This was a key factor in our decision to use a PV array over a solar water heater because when the building is not in use, the water heating system will be heating water that will rarely be used. This would result in an extension of the payback period of the initial installation cost. A PV array however, will continue to generate useful electricity for the main building when not in use by the Apple Spice Junction.

Based upon the appliances and electrical devices in the building, the power consumption of the Apple Spice junction was determined to be roughly 1000 kilowatt-hours per month. The average home uses 750 kilowatt-hours per month, making the Apple Spice junction a fairly accurate representation of home power consumption (Cool Flat Roofs, 2009). As such, the average home PV system is 2-4 kilowatts installed, accounting for 50-70 percent of the home's energy consumption (Cool Flat Roofs, 2009). Therefore, from the exhibit standpoint, the best way to relate to guests would be installing a residential-type system instead of trying to power the entire building and raising the installation cost.

This point can be further supported by our discussion with the solar contractors that visited the EcoTarium to assess the site including Advanced Energy Systems Development (AES), SunWind, and an internet estimate from New England Breeze. One of the major constraints on system size that the contractors highlighted was the availability of south-facing roof space. This constraint, as well as cost, is why system sizes are typically only 2-4 kilowatts and not larger to entirely supplement home power consumption. In the case of the Apple Spice Junction, the roof is flat and can accommodate more than 5 kilowatts of solar panels, but a large system will not be the best fit for its intended educational purpose.

Based upon all of the above factors, a 2-4 kilowatt photovoltaic array will best serve the needs of the EcoTarium. From the estimates we received from various solar contractors, we recommend the systems designed by SunWind, LLC. Based upon the average PV pricing of $7.50-$8 per watt installed, the systems designed by SunWind were actually below the average price range. For overall quality of service and pricing, the systems designed by SunWind will best accommodate the EcoTarium's need for budget pricing and a reliable installer. A summary of the pricing we received can be seen in Table i.

Table i: Installation Prices for Solar Photovoltaic Systems as Quoted

Company Name:	Proposed System Size:	Cost of System:	$/watt installed:
Advanced Energy Systems	1.6kW	$20,787.35	$12.99/watt
New England Breeze	4kW	$32,000	$8.00/watt
New England Breeze	2kW	$16,000	$8.00/watt
SunWind LLc.	5.06kW	$32,000	$6.32/watt
SunWind LLc.	2.53kW	$17,575	$6.94/watt

A Wind Anemometer Will Begin the Turbine Feasibility Study

In the future, the EcoTarium would like to install and exhibit a wind turbine in order to promote the understanding accepting, and adopting of wind energy. Much like the solar installation, it will need to be of the type that a homeowner would install in order to meet the goals of the EcoTarium. The major step that we took to help the EcoTarium realize this goal was the installation of a wind anemometer to study the wind on-site. We gathered existing wind data, available device options, and staff opinions in order to ensure that we provided the EcoTarium with a suitable anemometer for their needs.

Figure ii: Massachusetts wind resource map at 70 meters above the ground. The purple outline, including the EcoTarium, indicates a 6-7 m/s average wind speed. (Image credit: Wind Powering America, 2010)

Basic research on wind maps provided by Massachusetts Geographic Information Systems revealed that adequate wind speeds were very likely (see Figure ii). The maps displayed the winds in the area around the EcoTarium to be in the 6-7 m/s average range, and most small turbines require only 5 m/s to operate effectively (Holmes, 2010). With this initial data, we were able to move forward with a full wind study of the site and pursue and anemometer for installation.

After contacting several companies regarding anemometers, both AES and SunWind visited the site to speak with us and look at the proposed installation location. Both companies assessed an existing radio tower for use with the anemometer and gave us cost estimates regarding the device and installation (see Figure iii). While both provided reasonably priced options for anemometers, the labor cost for AES was much higher than that of SunWind. SunWind also provided us with a wider variety of options and once again had better overall service. The two anemometers proposed by SunWind included the APRS 6055 anemometer and the Davis Instruments Vantage Pro 2 Wireless weather station. Both systems would provide the EcoTarium with the necessary wind speed, direction, and consistency data necessary to make an informed decision on a wind turbine.

In order to decide which anemometer the EcoTarium would be interested in purchasing, we held a meeting with the staff to discuss the options presented by all parties. After we presented the options and the staff discovered that they could use the Davis instruments system in their upcoming renovations, the decision was made to purchase and install the Davis Instruments Vantage Pro 2 Wireless weather station. From here SunWind installed the device and data collection began so that the study could continue after our project was complete.

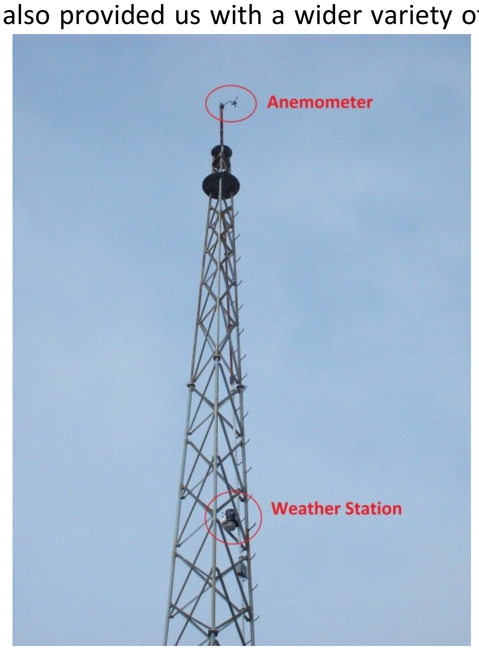


Figure iii: The EcoTarium's radio tower, complete with anemometer and weather station, roughly 90-100 feet tall.

Additional Factors to be Considered

After the completion of the anemometer installation, we provided recommendations for the continuation of our work. These recommendations included information such as wind study instructions, possible turbine options, and secondary uses for the turbine. These points are all crucial to the future installation of a wind turbine because they provide some of the steps necessary for installation.

The first step needed to move forward was determining a duration for the wind data collection. From our research we determined that the optimal timeframe for the study would be 12-15 months (Holmes, 2010). This allows for the data to be collected over a wide enough timeframe to account for seasonal changes in the wind. We also included methods for analyzing the final wind speed data and determining if a wind turbine is practical based on the gathered data.

There are several other steps that must be completed in order to move forward with a wind project. These typically include: (Green Energy Ohio, n.d.)

- *Evaluating the local wind resources*
- *Becoming familiar with basic wind energy information*
- *Completing an on-site wind resource assessment*
- *Conducting a study of the regulations surrounding an installation*
- *Choosing and evaluating a proposed installation site*
- *Selecting a turbine based upon available wind speed and energy needs*
- *Performing a project cost analysis*
- *Applying for grants*
- *Contacting the local zoning department and local utility*
- *Assessing avian concerns*

Many of these steps will only be completed once the wind speed is determined to be feasible for some type of installation. The completion of these steps provides an interested party with a plan for the installation of a turbine and the necessary data, such as cost and feasibility, to make an informed decision whether to proceed with such a project or not.

To provide the EcoTarium with some of the ground work to move forward, under the assumption that the wind will prove feasible, we researched some of the available turbine options. This research revealed that there are both vertical and horizontal axis turbines (see Figure iv), both of which have their pros and cons. For example, horizontal axis turbines, the most widely known type, are currently available in much larger sizes, but are dependent upon a fixed wind direction. The vertical axis ones however, are independent of wind direction, but are currently smaller scale and have smaller market.

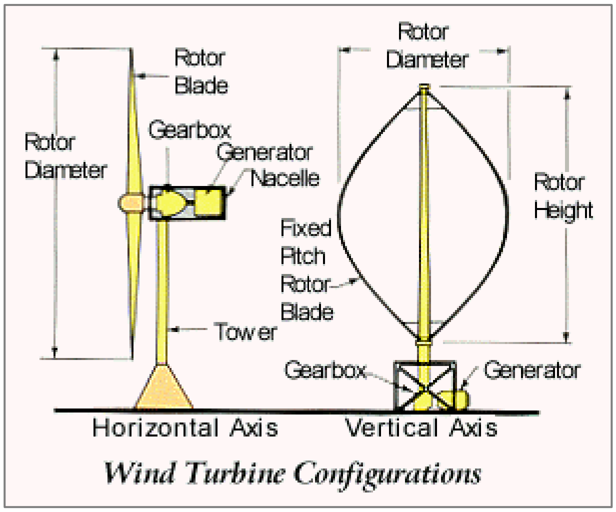


Figure iv: The two types of wind turbines. (Image credit: http://www.changetorenewables.com/)

From our discussions with SunWind and their site assessment of the radio tower, company President Timothy Holmes suggested that the typical consumer turbine, a 4kW installation, would in fact be compatible with the current tower structure. He also suggested that, pending the analysis by a structural engineer, up to 10kW could be installed for the current structure if some minor fixes to some of the structural members were made.

He even suggested a few turbines, including a few that are new to the United States and may be available at a discounted price.

One of the final things that we addressed was the possible use of the turbine for an avian wildlife study. The EcoTarium expressed interest in this as a future use for a turbine. This could reveal new information on the safety or dangers of residential wind turbines with respect to local avian wildlife. We recommended looking further into utilizing the wind turbine for this. Not only could it bring about new information regarding wind turbine safety, it could also give the EcoTarium an opportunity to receive grants for the research, helping to fund the turbine installation.

One of the best ways for the EcoTarium to move forward with this project will be to look at other wind-based projects. Through Worcester Polytechnic Institute and the Interactive Qualifying Projects, many such studies have been done on complete wind feasibility studies. Some of these projects include the *Auburn Wind Study*, *Winds of Worcester*, and *Sustainability Criteria for the Development of Wind Power in Worcester, Massachusetts* which can be used as resources for further research. By looking at these projects, the EcoTarium will have a more in-depth understanding of where exactly to move forward now that our project is complete.

Conclusions

From our research we can conclude that an interactive, engaging, and family friendly exhibit that creatively combats consumer uncertainties will best help the EcoTarium meet their goal of informally educating the public about renewable energy. In order to make this happen we have provided the EcoTarium with the ground work for solar and wind power installations. As a part of this, a residential-sized, photovoltaic array will be most appropriate for the Apple Spice junction on the EcoTarium grounds and SunWind, LLC is the recommended installer. This company has also provided the wind anemometer that will collect data for the next 12-15 months as part of a wind study to assess the feasibility of a turbine. Using our research and planning, the EcoTarium will be able to continue our work, and eventually produce a solar array, a wind-based installation, and the associated exhibits that educate the public about them. Through this, the EcoTarium will not only educate the public about renewable energy, but help them accept and adopt it as well and contribute to a cleaner, greener energy future.

1.0 – Introduction

In order to ensure the safety of our planet and way of life, fossil fuels must be replaced with cleaner, safer technologies in the near future. Renewable energies are commercially available as a replacement for fossil fuels, but people have yet to fully accept and adopt them into their lives. Working with the EcoTarium in Worcester, Massachusetts, we had a unique opportunity to take part in the solution to this problem.

The interface between renewable energy and society is gaining attention in many circles, including the EcoTarium. Polls conducted by Yale University have overwhelmingly shown that the American people are now concerned with our dependence on fossil fuels (DeFusco, 2005). Consequently, the demand for renewable energy technologies has sharply risen over the past few decades (Sawin, 2009a, 2009b).

Even with the rising demand for renewable technologies, a significant gap can be seen between public support and the actual usage of renewable energy. For example, only 8% of US energy production comes from renewable energy sources (*How Much Electricity*, 2010). This gap illustrates that the current methods for promoting the technology are insufficient to meet the wants and needs of the American people. By supplementing these methods with education, museums may have a greater role in promoting the adoption of new technologies

Through their role as educators, museums have a unique role in potentially closing the gap between the production and adoption of renewable energy. Creating museum exhibits that promote the understanding, acceptance, and adoption of renewable technologies will provide museum patrons with concrete examples of available technologies and how they might fit into their lives. Thus, guests will have the opportunity to see how they can save both money and the environment by switching to renewable technologies.

In this technological age however, people want to learn informally through interaction and not through direct instruction (Pitcher, 2010). They want to experience things and subsequently learn from these experiences. To solve the renewable energy problem, museum education has adapted to suit the ever changing educational needs of the public. In order for this education to succeed however, the diverse demographic of museum guests must be accounted for and their learning needs met.

The goal of this project was to aid the EcoTarium in the preliminary design stages of their wind and solar energy projects. We provided useful recommendations, enabling them to move forward with the design of these proposed installations. The exhibit concepts we proposed will be interactive, engage guests of all ages, and will informally teach museum guests about solar energy. At the same time, they will encourage the acceptance and adoption of the technology.

By dividing our goal into several logical and carefully planned objectives, we were able to give the project a clear direction and determine the proper methods to complete it. These objectives fall into two major categories: wind objectives and solar objectives. Our wind objectives included conducting the preliminary steps to assess the feasibility of a wind turbine installation and making recommendations to move forward with the study. Our solar objectives included determining the best options for a solar panel installation and generating design ideas for a solar energy exhibit.

These objectives were beneficial to meeting the goal of our project because each of them provided a systematic approach towards its completion. Our objectives progressed simultaneously, but together they benefited the overall goal. By providing the EcoTarium with the groundwork for a successful solar energy exhibit and the ability to continue a wind feasibility study, we were able to ensure our goal was met.

Following the discussion of our objectives, we will present our findings and recommendations and summarize their relevance to this project and its goal. Our findings will show that a change in the adoption rate of renewable technologies is possible and that the key to this change is guest involvement and continued education. To begin this project however, we first examined the relevant literature surrounding renewable energy and museum education in order to better frame our project and its goal.

2.0 – Background and Literature Review

The focus of our project was to examine renewable energy applications for the EcoTarium. In order to understand the challenges of these technologies, we first examined our current energy infrastructure and the adoption problems of renewable technology. We also examined the EcoTarium as a conduit for teaching about these technologies and how they can best present the technology to the public. To facilitate a level of understanding, accepting, and adopting, exhibits must not only seek to inform people but to provoke them to take action as well. Various literatures exist on these topics and will be examined to better frame our project and its goal. The logical starting point for such research involves examining the need for renewable technologies.

Our energy infrastructure must change and adapt to our increasing energy needs and the environmental problems of energy production. In the past, fossil fuels had a seemingly unending supply and there was an apparent disregard for their environmental effects. Today however, we know the supply of fossil fuels will likely peak in our lifetime and their use has been shown to cause global warming at an increasingly accelerated rate. In this electronic age, our energy demand is rapidly increasing and will eventually reach capacity. No longer able to sustain our future energy needs, this infrastructure must be replaced. Luckily, forward-thinking research has provided alternative energy technologies that will help alleviate society's dependence on fossil fuels.

Having this advanced technology means nothing however, if people will not use it. Renewable technologies have become widely available to consumers, yet there is a clear reluctance to invest in them. This may stem from a lack of conceptual understanding of the technology and a lack acceptance that these technologies are the future of energy. If people could learn to overcome their "phobias" surrounding renewable energy, the path to adoption would become clear.

The EcoTarium seeks to help the adoption problem by designing exhibits targeted to renewable energy problems and how green technology can help consumers. They will need to create exhibits that will engage their guests and provide them with a greater understanding of why the technology is needed. The Museum and their exhibits will also need to promote the acceptance and adoption of the technology so that a clean energy future becomes viable.

The role of a science museum such as the EcoTarium must therefore be to, "help change attitudes and behavior, to motivate, to inspire, to take information and make it meaningful, interesting, and exciting" (Veverka, 1994. p.20). The objective of the museum should therefore be to, "take the visitor through the process of sensitivity-awareness-understanding-appreciation and finally, commitment" (p.20). Through this process and our project, people will not only learn about clean energy, but will be influenced to accept and adopt the available technologies into their lives.

To best frame our project, this chapter will elaborate on the following themes. The problem of fossil fuels will be presented along with renewable energy solutions. We will also examine how the government has attempted to promote renewable energy and discuss the problems with their adoption. Once the adoption problem has been addressed, the solution the EcoTarium seeks to provide with energy demonstration projects and exhibit design will be presented. Finally, the design and features of a successful museum exhibit will be explored to determine how best to move forward in our own project. In order to begin however, the problem we are addressing must be further explored.

2.1 –Renewable Energy Topics and Issues

Renewable energy is a highly publicized topic in the developed world. We are constantly reminded of the negative effects of global warming and our dependence on foreign oil. Renewable energy is presented to us as the solution to this energy issue, but what exactly is renewable energy? More importantly, what does this information do for the average consumer and how does it affect their energy decisions?

The answers to these questions can be found in an analysis of relevant renewable energy technologies and the current market for them. Through the following sections, we will address what constitutes renewable energy, why it is necessary, and the options and incentives available to consumers. This will reveal an unforeseen problem with renewable energy: consumers are reluctant to accept and invest in the renewable technologies. The solution to this problem was the core of our project work.

2.1.1 – Defining Renewable Energy

Renewable energy can be defined as any kind of fuel that comes from sources that are, "inexhaustible within the time horizon of humanity" (Quaschning, 2005. p. 20). Renewable sources include sunlight, wind currents, running water (such as rivers and waterfalls), and geothermal heat (Carless, 1993). As these sources can be naturally renewed, it would be nearly impossible to entirely consume them.

In contrast, "non-renewable" energy comes from exhaustible sources. The most obvious examples are oil, coal and natural gas, which come from deposits of finite size (Quaschning, 2005). As these fuels were synthesized over millions of years, they cannot replenish themselves at any useful rate. Analysts have predicted, and it has been observed in several oilfields, that the rate of fossil fuel production will peak in our lifetime. After this occurs, supplies will enter a terminal decline until they are entirely consumed (Rowe, 2010). This creates the problem that renewable technology can solve.

2.1.2 – The Diminishing Oil Supply

Fossil fuels, the main energy supply for the world, are exhaustible and are becoming scarce. When we run out of them in the near future, fuel prices will surge, food prices will skyrocket, and products that depend on petroleum will become increasingly expensive (Rowe, 2010). Renewable energy sources can prevent these issues as they will not be consumed in our lifetime.

The demand for energy can only increase over time. Through industrial development and population growth, our energy requirements will continue to rise. Attempting to satisfy this increasing demand, oil companies have searched in more and more remote places for oil. This may result in more offshore wells or a means to fabricate oil, but these methods will come at a cost. These methods will not only be more expensive, but more dangerous as well (Rowe, 2010).

A shortage or sharp price increase of oil will become an issue for the industries that depend upon it, which will ultimately affect product availability for consumers. Many products that depend on oil for production, such as fertilizers, detergents, most plastics, and even vital supplies of food, will become scarce and expensive as oil supplies run out (Rowe, 2010). For example, in agriculture, oil is heavily used in farming equipment and various high-yield agricultural methods. As the oil supplies decrease, these methods could not be used in their current capacity. Since these methods are necessary to sustain the current population, the price of food would spike, and unprecedented famine would take place. This is a serious effect the oil problem may have in the near future.

According to the Hirsch Report on the *Peaking of World Oil Production* (2005), “without massive mitigation more than a decade before the fact, the problem [of oil] will be pervasive and will not be temporary” (p. 64). Consequently, our current energy path is both unsustainable and a critical threat to world functions. The diminishing supply is not the only problem however, as the burning of fossil fuels has had serious environmental consequences as well.

2.1.3 – The Environmental Consequences of Fossil Fuels

In addition to the serious economic issues, fossil fuels have been proven to cause environmental destruction. Some experts predict that if our current emissions rate is not slowed, the earth will undergo a radical and severely problematic climatic change (Carless, 1993). The burning of fossil fuels produces toxic waste that pollutes our atmosphere (Tester, 2005). According to Quaschning (2005), “the burning of fossil fuels emits the largest amount of anthropogenic carbon dioxide” of any source in the world (p. 11). Carbon dioxide emissions have been traced to an increase in the mean global temperature of the earth. This increase in temperature has caused the melting of ice caps, leading to rising ocean levels, and an increased intensity and frequency of natural disasters.

In stark contrast, renewable energy sources are much more forgiving to our environment. These technologies will help prevent further environmental destruction and economic ruin. They do not produce the types of toxic byproducts that are associated with the damaging effects of fossil fuels and will lower our dependence upon them. An analysis of these technologies and the associated investment incentives must be assessed in order help frame our project's problem.

2.1.4 – The Promotion of Renewable Energy

A wide selection of technologies and financial incentives are available to consumers. These technologies include solar cells, geothermal heat pumps, hydrogen fuel cells, and wind turbines. Financial incentives for consumers include tax credits, net metering, and rebates. The combination of these technologies and respective incentives aim to guide consumers to renewable energy and a clean energy future.

Each of the above technologies provides a solution to our energy problem. These technologies help reduce our dependence on fossil fuels and ultimately save consumers money. Renewable energy technologies utilize renewable resources such as sun, wind, and the natural heat of the earth to produce electricity and heat. This will reduce the energy that must be bought. For example, an average household solar installation of 2-4 kW can reduce energy bills by 50%-70% (Cool Flat Roof, 2009).

In addition to energy savings, financial incentives are available to promote the installation of these technologies. For example, a 30% tax credit is available to consumers for certain purchases including renewable technologies and higher efficiency appliances (*American Recovery and Reinvestment Act of 2009*). If a consumer's renewable technology system can produce more electricity than is needed, they can even sell electricity back to the grid through net metering, further lowering energy costs (Bradford, 2006). The incentives and policies have thus aligned so that it is more affordable to begin the transition to renewable energy technology, but this means nothing if people will still not invest in them.

2.1.5 – The Uncertainties of Renewable Technology Installations

Although the current solutions to our energy problem are available to the public and have been incentivized by policy change, consumers are still hesitant to invest in renewable energy. This is evident as only 5% of the nation's energy is derived from solar and wind technologies (*How Much Electricity*, 2010). When compared to the 92% of Americans that support renewable energy, a large disconnect can be seen between public support and actual usage (DeFusco, 2005).

This low adoption rate among consumers can be linked to several factors. According to California Energy Commission, the hurdles for investing in renewable energy systems are as follows (Cronk & Esternon, 2002).

- High initial investment, with unclear return on investment.
- Lack of knowledge regarding the equipment, technological application, and availability.
- A perception that the installation process is difficult and complicated.
- Lack of trusted references from (friends, neighbors, etc.) that have installed their own solar or wind systems.
- Difficulty in finding a qualified installer.

While people realize renewable technology can lower their energy bills, they often only see the high initial cost without fully understanding their return on investment. This is a major factor that is holding back the widespread use of renewable technologies. For example, the payback period can exceed 10 years, which may deter consumers (Cool Flat Roof, 2009). While the financial incentives are available that can help this, people may not fully understand what they are or how to get them. Knowing that the installation is expensive and not knowing how much can be saved discourages many potential customers.

A lack of technical knowledge may also deter potential customers. All of the relevant technical data such as system size, electrical output, and installation procedures can overwhelm many consumers. People realize that sources such as wind and sun are necessary to power renewable technologies, but are unaware of the actual requirements. Consumers may also be unaware of the terminology associated with these installations such as kilowatt installed and kilowatt-hour. While consumers may be interested in renewable energy technologies, a lack of relevant knowledge may prevent consumers from pursuing them.

As a result of this lack of relevant knowledge, consumers may perceive the installation process as difficult and complicated. Since many components are involved in an installation such as building permits, building inspections, utility inspection, and net metering agreements, consumers may not know where to begin. This deters consumers from installing a system as they are unaware whether their location is adequate for installation and how to properly begin the installation.

Due to the recent emergence of renewable energy technology there is a limited field of qualified installers. In addition, consumers have very few or no friends and neighbors who are familiar with the technologies or own a system. This leaves the consumer with no one to consult about potential installations. Without accessible references or knowledge of reputable installers, consumers are dissuaded even more from installing a renewable energy system.

These hurdles are a major setback for the adoption of renewable technologies. Consumers with the aforementioned concerns will not adopt renewable energy unless their uncertainties can be resolved. This problem is evident as only 200,000 U.S. homes use some type of solar photovoltaic system, out of an estimated 114 million U.S. households. (Solar Development, 2007; U.S. Bureau of the Census, 1996). Clearly there is a disconnect between the public support and the actual adoption rate, a serious problem we sought to address.

2.1.6 - Final Notes on Renewable Energy

Our current energy path is clearly unsustainable as well as an obvious threat to our environment and our lives (Carless, 1993). Already, there are many technologies that utilize renewable energy sources to suit nearly all our energy needs. Nonetheless, our energy demands are met primarily by fossil fuels and renewable energies only account for a small portion of that need.

The barriers to the acceptance and usage of these technologies must be brought down before the renewable energy industries can fully succeed. People are uncertain about these technologies and are thus hesitant to invest in them. As these technologies are widely available and the economic advantages are numerous, the final step to widespread adoption is educating our communities about what renewable energy can do for them. This will promote the understanding, acceptance, and adoption of renewable energy. In the local, Worcester community, the EcoTarium would like to step up to and face this challenge.

2.2 – The EcoTarium

The EcoTarium, a science and discovery museum in Worcester, Massachusetts, seeks to aid the community's adoption of renewable energy. They provide informal education through interactive exhibits that engage people of all ages. By adding renewable energy technology to their repertoire, they can give their guests the necessary details on the importance of switching to renewable energy sources. This information can alleviate some of the public uncertainties discussed earlier and possibly convince some of their guests to make the change.

We helped the Museum play the role of mediator and educator in the adoption of renewable energy. With our contributions to this role, the Museum can help spark the change that is necessary to bring a clean energy future to our community and our world. This potential can be seen by taking a look at what the EcoTarium offers as a museum, their goals for a better world, and how their mindset and exhibit design practices are perfectly geared for effective renewable energy exhibits.

2.2.1 – About the Museum

The EcoTarium is a museum dedicated to teaching children and adults about science and nature. Every day, they "bring the wonder of science and nature to life…[for the] thousands of schoolchildren from across the region" (EcoTarium, 2009). In order to do this, they create unique interactive and exploratory exhibits. Parents and their children learn about science and nature at the EcoTarium by taking a treetop walk, viewing the galaxy in a digital planetarium, visiting the many wildlife creatures that reside on the campus, and playing and learning with interactive science exhibits (EcoTarium, 2009). Each of these activities lets guests "discover" the natural world, which is part of the Museum's mission.

The mission, as stated by the EcoTarium, is, "to contribute to a better world by inspiring a passion for science and nature through discovery" (EcoTarium, 2009). By letting their guests interact with and explore their exhibits, the Museum inspires a greater appreciation of the natural world. A more appreciative community can make a difference, no matter how big or small, in the well-being of our environment, our wildlife, and our planet. This vision of a brighter future fuels their mission to contribute to the community.

2.2.2 – Furthering the Mission: Renewable Energy Exhibits

To further their contributions, the EcoTarium is looking to create renewable energy exhibits (Pitcher, 2010). They want to give their guests the chance to explore renewable energy and find a greater appreciation for it. In this way, they can help the community make the switch to a cleaner, safer source of energy.

The EcoTarium can address people's uncertainties by providing renewable energy education through their exhibits. They can give parents and their children "informal education" on renewable energy that they might not receive in the formal curriculum (Pitcher, 2010). Discovery-based exhibits that are designed to engage people of all ages can achieve this. Children can interact with the exhibit and gain basic knowledge about renewable energy, and adults can utilize more informational components to better understand the technology and benefits (Pitcher, 2010). By giving their guests the opportunity to explore renewable energy technologies, they can instill a greater understanding and appreciation for them and alleviate common uncertainties.

2.2.3 – Final Notes on the EcoTarium

With a mission for helping the world and with experience in interactive exhibits, the EcoTarium has the mindset and the tools to help people better understand renewable energy. We ultimately sought to help them design and create the exhibits to accomplish this. The question then became, how could we design renewable energy exhibits that cater to their diverse audience and provide the level of education to encourage acceptance and adoption of renewable energy? To begin answering this question, we next examined the relevant criteria for designing effective museum exhibits.

2.3 – Best Practices for Exhibit Design

As the EcoTarium was in the midst of planning renewable energy exhibits, it was important to know what makes an exhibit successful. It is the Museum's goal to help their guests understand, accept, and adopt renewable energy and it was our job to help make this happen. To do so, we needed to present concepts, such as return on investment and affordable system sizing, which would help alleviate common uncertainties about installing renewable energy technology (See Section 2.1.5). It was therefore important to study exhibit design processes and criteria in order to appropriately present these concepts. A discussion of our criteria will therefore follow, including successful family exhibit principle, learning levels, performance indicators, and an integrated discussion of how public uncertainties can be addressed through exhibit design.

2.3.1 – Characteristics of Successful Family Exhibits

An important step in designing a successful family exhibit is understanding what actually makes a good exhibit. We had to examine what characteristics of exhibits make them family-friendly and encourage informal, lifelong learning. Several studies have been done on museum education, but a study by the Philadelphia/Camden Informal Science Education Collaborative (PISEC) reveals many of the important factors for encouraging family learning. These factors and characteristics are crucial in designing an exhibit that will not only teach, but help consumers overcome their uncertainties towards adopting renewable energy.

The PISEC study found that most visitors enjoyed museums and viewed them as educational tools. As such, good exhibits have been described by visitors as being self-explanatory, labeled with simple, large type, not crowded, interactive, multi-sensory, friendly, and inviting (Borun, 1998). From this feedback, seven characteristics for successful family exhibits were developed by the PISEC study. As shown below, Table 1 depicts the seven characteristics that will best predict an effective family experience (Borun, 1998).

Table 1: Family-Friendly Exhibit Criteria

Seven Characteristics
1. *Multi-sided*: The family can easily crowd around the exhibit
2. *Multi-user*: Interaction allows for several sets of hands (or bodies)
3. *Accessible*: The exhibit can be comfortably used by children and adults
4. *Multi-outcome*: Observation and interaction are sufficiently complex to foster group discussion
5. *Multi-modal*: The exhibit appeals to different learning styles and levels of knowledge
6. *Readable (Understandable)*: Text (Presentation) is arranged in easily-understood segments
7. *Relevant*: Cognitive links to visitors' existing knowledge and experience are provided

Although these seven characteristics seem to be obvious in designing an interactive exhibit, they are rarely all present at once (Borun, 1998). This can present problems since the educational value of the exhibit will only be maximized if all can be accomplished. The importance of a multifaceted exhibit can therefore be seen as a typical visitor will only retain 10 percent of what they hear, 30 percent of what they read, 50 percent of they see, and 90 percent of what they do (Veverka, 1998,pg25). The best family exhibit will thus present all elements to some degree with a focus on interaction. Taking into account how people learn from such an exhibit was the next important step in reducing renewable energy uncertainties.

2.3.2 – Learning Level Criteria

An important step in understanding an exhibit is to determine if people are actually learning from it. This is essential because, "without a fairly clear notion of how people learn, it is not possible to develop a coherent education policy" (Hein, 1998, p. 16). The PISEC case study also provides a closer look into measuring group and family learning. According to the study there are three levels of learning which include identifying, describing, and interpreting and applying. These levels, "reflect the increasing richness of detail and complexity in both the group's understanding of exhibit-based information and their connections to prior knowledge" (Borun, 1998, p. 14). Below, Table 2 reveals what each learning level entails and briefly describes how the levels progress.

Table 2: Description of the Learning Levels

Level	Description
ONE	
Identifying	▪ One word statements ▪ Few associations to exhibit content ▪ Connections to content miss the point of the exhibit
TWO	
Describing	▪ Correct connections to visible exhibit characteristics ▪ Connections to personal experience based on visible exhibit characteristics, not concept
THREE	
Interpreting and Applying	▪ Correct statement of concepts behind exhibits ▪ Connection to personal experience based on exhibit concepts

These Learning Levels provide a concrete foundation that can be used for any exhibit and are the basis for a set of criteria for successful design. The information above allowed us to study the associations and personal connections visitors have during exhibit interaction, a large part of informal learning. Although the learning levels reveal a groups' overall understanding of the exhibit, a set of performance indicators were next observed to determine which learning level a group or individual has progressed to.

2.3.3 – Performance Indicators

The performance indicators found by the same PISEC study include five behaviors that can be observed to distinguish between the previously mentioned learning levels. These five behaviors include:

- Asking a question
- Answering a question
- Commenting on the exhibit or explaining how to the use the exhibit
- Reading text aloud
- Reading text silently

The study further found that "since the five behaviors had a significant relationship to Learning Levels, they were considered to be learning indicators; that is, if these behaviors were seen, it could be inferred that learning was taking place" (Borun, 1998, p. 18). This is an important concept that allows exhibit designers to get an idea of the level of learning that is taking place in their exhibits so they can more effectively plan for future exhibits.

Unfortunately, these performance indicators are based on exhibits where reading is a major component. When designing an interactive exhibit, it is still possible to reach the maximum learning potential with less reading content. It has been found that, "In exhibits designed to convey concepts experientially, it may be possible to reach Level Three by observation and interaction" (Borun, 1998, p. 18). The EcoTarium may therefore want to replace much of their written content in new exhibits with hands on activities and group collaboration. With a basic understanding of how to measure the learning process, we compiled a final list of criteria to design an exhibit that will foster the understanding, acceptance, and adoption of renewable energy.

2.3.4 – Compiling the Criteria

Our research provided us with the information needed to compile a set of criteria that will be universal for all types of museums and interactive exhibits. This ensured that a successful solar exhibit could be designed. More importantly however, this will ultimately help change guest behavior towards solar concepts and technology.

Based upon the exhibit research above, the final set of criteria we implemented is as follows:

- The seven characteristics of a successful family exhibit
- The three learning levels
- A modified set of performance indicators

We implemented all of the attributes of a family-friendly exhibit which include m*ulti-sided, multi-user, accessible, multi-outcome, multi-modal, readable,* and *relevant*. The three learning levels remained the same as they reflect the increasing richness of detail and complexity in both the group's understanding of exhibit-based information and their connections to prior knowledge (Borun, 1998). Our performance indicators however, changed slightly to distinguish between the learning levels and accommodate an interactive exhibit. The performance indicators used included, *asking a question, answering a question, commenting/explaining about the exhibit*, and *observation of interaction*.

This compilation of our criteria provided insight on how to change visitor perception of and behavior toward renewable energy. First, exhibit concepts must present information to guests about the issue and the use of solar energy. Then, they must aim to create and enhance visitor awareness of the energy issue and how solar energy can help solve it. Finally, the exhibit must provide motivation to change and promote guest action beyond their museum visit (Veverka, 1998, pg. 13). In order for a renewable energy exhibit to actually succeed however, our criteria had to be applied to alleviate guests' uncertainties regarding renewable energy investments.

2.3.5 – Alleviating Uncertainties through Exhibit Design

By the nature of the proposed wind and solar installations, the exhibits that are associated with them will be multi-faceted. The installation of a wind turbine and solar panels will provide the opportunity for guests to view actual renewable energy solutions. In addition, guests will then have the opportunity to interact with an exhibit explaining the relevant concepts regarding the technology, its installation, and how it can help them reduce their energy consumption and bills. Thus, by reexamining the public uncertainties toward renewable energy (see Section 2.1.5) we had a better understanding of how to help guests overcome them.

One of the major concepts that exhibits promoting renewable energy must cover is the explanation of the technology and its relative cost. One of the biggest problems is that people are uncomfortable with what they are unfamiliar with or do not understand. By explaining the relevant technological concepts in enough detail so people can understand them, people will be more comfortable with the technology. In addition, the return on investment for renewable energy must be presented in a way that is interactive and easy to understand. Showing people that their initial investment will save them money over time and clarifying what the technology can do for them, will help people see what is possible and how long it will take to get there. If people have a better idea of what they are spending their money on, they are more likely to make an informed investment decision.

Even with this financial and technical knowledge in hand, people will still need guidance on where to turn to start a project and who to contact. According to Timothy Holmes, President of SunWind, LLC, one of the biggest issues with renewable energy is the lack of advertising (Holmes, 2010). People may have interest in renewable energy, but without advertising to help people find installers, the search can be far more complicated. If an exhibit were to properly explain the installation procedures, and potentially advertise for reputable installers, guest perceptions of a difficult and complicated installation process could be erased. At the same time, guests would be able to get an idea of which installers are reputable and potentially get a few industry contacts from take home pamphlets. The EcoTarium could therefore act as the friend or neighbor who has experience in renewable technologies, helping guests become more comfortable with adopting renewable energy.

2.3.6 – Summary of the Best Practices

An interactive exhibit designed with the above criteria and concepts will be important to solving the adoption issue and helping combat consumer uncertainties surrounding renewable energy. Designing around these criteria will help maximize the information conveyed and retained by guests. One of the major challenges of the design process will therefore be to present the essential concepts to combat consumer uncertainties while also designing to the criteria necessary for a successful interactive and family friendly exhibit. Initiating this overall design process and determining how to present relevant concepts therefore began with our own understanding of the relevant technologies including wind and solar power.

2.4 – Solar Technology for the EcoTarium

Like other renewable energy technologies, solar panels provide a viable alternative to fossil fuels, but are not yet used to a high degree. In order to inform visitors about this issue, the EcoTarium will be investing in solar panels as part of their alternative energy exhibits. They believe that in addition to reducing their energy consumption, solar panels would be a useful display for their guests. The Apple Spice Junction food shop, located on their campus, is the potential target for this project (see Figure 1). Part of our work involved helping them determine the feasibility, methods, and costs for a solar panel installation at this site. The other part of our work was to suggest ideas for a renewable energy exhibit. We believe that solar panels are a good choice of renewable energy technology in this regard.

Figure 1: Front view of the Apple Spice Junction

2.4.1 – Why Solar Panels?

Solar panels can provide a clear showcase of renewable energy on the EcoTarium campus. Installed on the roof of the Museum's Apple Spice Junction, the solar panels will be clearly visible and attract attention. This attention can be the focal point for sparking guest interest in renewable energy.

The EcoTarium can then provide information that will relate to the guests. Such information can include the amount of money a person can save per year or the financial incentives that can help them pay the initial investment. It can also include details about how solar power will help cut down fossil fuel usage and emissions. This kind of information will be more understandable for the average visitor as they will be able to physically see the technology whose benefits they are reading about. This can help visitors relieve their uncertainties, discussed in Section 2.1.5, which would help them decide whether or not to make the switch. With these goal-oriented details in mind, solar panels are clearly a good choice for an exhibit.

2.4.2 – Solar Power Exhibit

As the EcoTarium has decided to install solar panels, we will be brainstorming ideas for possible exhibits. Our ideas will try to bring important, relevant information to the Museum's visitors. To do this, they must adhere to the criteria discussed in Section 2.3, and as such, we will be brainstorming with those criteria in mind.

Several aspects of solar panel systems easily satisfy some of the important criteria. First, they are *multi-sided*, as many people can gather around or eat in front of the building they are installed on. Second, with a few basic displays detailing information about solar panel systems, we can easily achieve *readability* and *relevancy*. They may even feature the *multi-outcome* characteristic to an extent, as visitors can discuss how they work or whether or not they think solar panels would be practical on their homes. However, to satisfy other criteria, or to help reinforce the ones described here, we must research and identify complementary exhibit designs.

Various complementary components can be researched to help fulfill the criteria and get the important information across. For instance, an interactive portion can make the exhibit more *accessible* to children. In addition, several interactive modules ranging in knowledge level can satisfy the *multi-user* and *multi-modal* criteria. These points, however, are very general and abstract, meaning that research and brainstorming will need to be done to design the actual components. Before we can do this, we must take into account the technical portion of the work, starting with the available technologies.

2.4.3 – Available Technologies

The two major types of solar panels available are photovoltaic and thermal. They are used to convert sunlight into electrical and thermal energy, respectively. Both of these were considered for use by the EcoTarium.

Photovoltaic solar panels convert sunlight into electricity. To operate properly, they require nearly direct, unobstructed sunlight to operate properly, and a large array may be required to fully power a residence (AltE, n.d.).The electricity generated by the system can be used to power any household appliances, and can even be fed back into the electrical grid, significantly reducing energy bills (Premier Power, 2010). To demonstrate this cost reduction, the EcoTarium wants to use The Apple Spice Junction as a site project. This building's electrical requirements are similar to that of the common household and it may be possible to install enough panels to completely power it. Even if the panels do not fully accommodate the energy demand, they can serve as an exhibit for the EcoTarium that is related to the daily life of the visitors.

Thermal solar panels utilize sunlight for water heating. These panels circulate water through the panels to heat it. The heated water can then be stored in a tank for later use. Like the photovoltaic panels, a solar thermal hot water system can significantly reduce energy bills. This system could be utilized in the Apple Spice Junction building to provide hot water for the bathrooms and kitchen area.

These two types of systems represent the basic options for the EcoTarium. Both are practical applications for the Apple Spice Junction building that can also be used for exhibit purposes. Our recommendations will include which system, or what combination of both, would be the most beneficial for the Museum. However, there are important considerations in determining which system is most beneficial.

2.4.4 – Important Considerations

In order to ensure that it is feasible to install a system, a company must consider the amount of available sunlight, energy demand, and roof structure of a building, as well as the cost for the final system. In this case, a solar installation company would apply the following consideration to the Apple Spice Junction building.

First, they would measure the amount of sunlight available at the Apple Spice Junction to ensure the system will be effective. This would also include designing arrays of specified power output, which we can then compare to the energy demand of the building. Finally, they will present us with the costs for the system and the installation.

After compiling the information collected from the solar companies, the EcoTarium would have to hire a Structural Engineer to perform mandatory roof structure assessments to ensure that the building could bear the extra weight of solar panels. This will free us from having to dissect all the details of installing the system.

However, the EcoTarium, as a non-profit organization, does not have the disposable income to fund the installation and they will have to apply for grants. This means that they must have a proposal for a system that includes its cost. A designer will provide the EcoTarium with a range of designs and respective costs. These designs could range from completely powering the Apple Spice Junction to powering a portion of the building. We will then weigh the options, discuss them with the Museum staff, and make recommendations to move forward based on their needs.

2.4.5 – Moving Forward

There are several choices the EcoTarium has for installing a solar energy system. They can utilize a photovoltaic system, a solar hot water system, or both. We can put together a set of choices and make recommendations for a system that is cost effective and can be used for a future exhibit. Although the

Museum does care about fulfilling their energy demand, they are more interested in creating an exhibit. In order to assist them, we will also provide them with ideas for how they can turn their solar panel system into an informational and effective exhibit.

2.5 – Wind Technology at the EcoTarium

Wind turbines provide another option that can harness a renewable resource. As with other renewable technologies, wind turbines have a low adoption rate among consumers as well. Currently, only 9% of all renewable energy is produced from wind turbines (*How Much Electricity*, 2010). In order to inform visitors about this issue, the EcoTarium has expressed interest in the future installation of a residential-type wind turbine as part of their upcoming Energy Trail exhibits. Before investing in a wind turbine and a future wind energy exhibit however, a wind feasibility study must be conducted to determine if a wind turbine is a viable investment.

2.5.1 – Wind Turbine Feasibility Studies

There are several steps which are required to determine the feasibility of a wind turbine. Typically, these steps include: (Green Energy Ohio, n.d.)

- *Evaluating the local wind resources*
- *Becoming familiar with basic wind energy information*
- *Completing an on-site wind resource assessment*
- *Conducting a study of the regulations surrounding an installation*
- *Choosing and evaluating a proposed installation site*
- *Selecting a turbine based upon available wind speed and energy needs*
- *Performing a project cost analysis*
- *Applying for grants*
- *Contacting the local zoning department and local utility*
- *Assessing avian concerns*

The completion of these steps provides an interested party with a plan for the installation of a turbine and the necessary data, such as cost and feasibility, to make an informed decision whether to proceed with such a project or not.

Within the scope of our project however, the main concern will be the evaluation of the local wind resources and the preparation for and commencement of the on-site wind resource assessment. These steps include looking at wind maps for previously gathered data and a wind study that is used to determine the consistency, strength, and direction of the wind. The wind maps will be supported by the wind study and will determine what size, if any, wind turbine can be installed.

The major tool for conducting the on-site wind assessment is the wind anemometer which is used to measure the consistency and strength of the wind throughout the period of the wind study (Manwell, 2002). A wind study should collect approximately 12-15 months of data (Holmes, 2010). From this data gathering, a minimum wind speed of 5m/s is required to install a small wind turbine (Kelly, 2009). After data collection is complete, the EcoTarium will have the information to determine if they have the proper wind speeds to utilize a residential-sized turbine.

2.5.3 – Deviations from a Typical Feasibility Study

In a typical turbine installation, a tower must be erected to house the turbine at the proper height. In the case of the EcoTarium however, a pre-existing radio tower is adequate to support an anemometer and possibly a small turbine in the future. The top of this tower, seen in Figure 2, is conveniently located 30-40 feet above the tree tops, making it an ideal location for an anemometer or turbine (Holmes, 2010).

Figure 2: The EcoTarium's radio tower, complete with anemometer and weather

This alters the feasibility study slightly because the anemometer can now be placed on the tower at the same height the turbine would go instead of on a pole on the Museum's roof. Additionally, a structural analysis of the tower must now be included in the study to assess the structural integrity of the tower. Most importantly, utilizing this tower may ultimately save the EcoTarium roughly $20,000 in the installation process as a new tower or pole for the turbine will not be necessary (Holmes, 2010). While the existence of this tower changes the study procedure slightly, it will ultimately save money and make the installation of a residential-type turbine easier.

2.5.4 – Why a Residential Wind Turbine?

The EcoTarium is interested in the purchase of a residential-sized wind turbine to further their goal of helping people understand, accept, and adopt renewable energy. By installing a residential type turbine, EcoTarium can relate to the interests and needs of their guests. When guests visit the Museum, they will be able to see the type of turbine and size that they could install in their own home. This visual evidence of renewable technologies will help guests overcome the uncertainty of what type of system they could install. Seeing a working example of something they could actually use, may in itself help people become more comfortable with the technology.

2.5.5 – Wind Technology Summary

Using the feasibility procedures outlined above, the EcoTarium will have the basic steps to complete a wind feasibility study of their site once our project has ended. In the scope of our project, these steps include the analysis of recent and annual wind maps and the collection of present wind data via the installation of a wind anemometer. Utilizing an existing tower for the project, they will save both time and money in the installation of a residential-type turbine. This turbine will eventually show guests what they can install for themselves at home. The EcoTarium will thus be able to use our work to further the study and hopefully install a wind turbine on-site.

2.6 – Research Summary

Renewable energy must be adopted to replace fossil fuels. Our current overdependence has led to environmental destruction and will lead to further crises when supplies run short. Renewable energy is a clean, viable solution to this issue. Consequently, policies have been changed and financial incentives have been provided, but people are still not adopting in large numbers.

The EcoTarium wishes to play a role in helping people adopt renewable technologies. Their focus on the natural world and their dedication to contributing to a better world places them in a position to take this role. Exhibits produced during their renovation can educate visitors about renewable energy. The EcoTarium hopes to inspire people to explore their renewable energy options once they leave the Museum. They can accomplish this by designing exhibits that engage their diverse audience.

Using our outlined criteria for exhibit design, the EcoTarium will be able to integrate their own exhibit design process with our research to create effective exhibits. The interactive, family-friendly exhibits that result from these criteria will engage both children and adults in the learning process. These criteria will be critical to designing a successful exhibit and properly educating guests.

The creation of a successful exhibit will aid the EcoTarium in bringing awareness of renewable energy to the community. Having the information and the criteria to do so, the only remaining issue was to apply these criteria. We conducted research on both solar and wind technologies and discovered the steps necessary for their installation. Using this technological research, our criteria, and a better understanding of our problem, we were then able to proceed with our project.

The next step we took was to explore the proper methods for building successful exhibits. Research was done on how to build an exhibit that meets these criteria while accurately presenting renewable energy. Once this was done, recommendations on how to present renewable energy technology at the EcoTarium were made. Accordingly, our methods for completing this project will be discussed in the following chapter.

3.0 – Methodology

In order to complete the goal of our project and assist the EcoTarium with the preliminary steps of their energy projects, we had to complete several objectives. Dividing our project goal into several logical, well-reasoned objectives gave the project order and allowed us to outline the proper methods to complete it. Though the goal of our project was to aid the EcoTarium in the preliminary stages of their designs and feasibility studies, we completed our work so that it could be used as a base for future work.

After completing our research, our first steps were to work towards installing an anemometer (see Literature Review 2.5.3) and gather site information for a solar installation (see Literature Review 2.4.4). Our first two objectives included conducting the preliminary steps to assess the feasibility of a wind installation and determining the best options for a solar installation. These progressed at the same time as gathering anemometer and solar information involved many of the same companies. From this, we determined a proposed installation type and associated installer. As a result we generated ideas for presenting solar concepts to the public based upon proven criteria for exhibit design (see Literature Review 2.3.5 and 2.4.2). Due to the previous objectives, we were able to make recommendations for future work and studies so these projects can progress. This section will summarize the collective methods of our project work and how they were relevant to completing its overall goal.

3.1 – Objective One: Preliminary Wind Study

In our first objective we conducted the preliminary steps of a wind study for the EcoTarium. This objective fulfilled a request from the EcoTarium to collect wind data and present it to the public. Ultimately, the goal of this wind study was to determine the feasibility of and install a wind turbine on the EcoTarium campus. This full wind feasibility study however, was outside the scope of our seven week project. The scope of our project included starting the wind study so the EcoTarium could continue collecting data when our project was complete. In order to complete this objective we had to study the wind charts for the Worcester area, investigate wind measuring devices and installers, present our findings to the EcoTarium's staff for review and device selection, install the device, and collect and display the data for future use. This section will discuss these tasks in greater detail, beginning with a discussion of the wind maps for the Worcester area.

3.1.1 – Worcester Wind Map Study

To first determine if a wind study was warranted at the EcoTarium site, we first examined the existing wind data for the Worcester area. Using the wind maps for Worcester, Massachusetts, we located the EcoTarium and assessed the projected wind speed for the site (see Appendix D). We then cross referenced this data with the minimum requirements of wind turbines. From this, we determined if further study was warranted.

3.1.2 – Anemometer and Installation Quotes

As a result of the wind map study, we determined that further wind studies were justified for the EcoTarium site. Therefore, we researched anemometer pricing and installers as our next step. The proposed installation site was an old radio tower that had been out of service for more than ten years. Using this tower for an anemometer would provide a height necessary to collect accurate wind data.

We contacted several companies including Advanced Energy Systems Development (AES) and SunWind, LLC. for device pricing information and installation. Both companies seemed interested in the project and sent representatives to analyze the site. We also requested and were provided with preliminary project proposals from each installer including a price quote for the device and installation to the tower. The next step was to select a device based upon the options presented, but we needed to consult the EcoTarium staff before an installation could proceed.

3.1.3 – Selecting a Device

Based upon the collected price quotes, we presented the EcoTarium staff with their anemometer options. The pricing and installation costs, ease of use, and potential for display in the museum were all presented to the staff in a project meeting that we requested. Based upon our recommendations and the information provided, the EcoTarium staff reached a decision on a device to install. Once a final decision was reached, we contacted the selected company to proceed with installation.

3.1.4 – Anemometer Installation

The selected anemometer was ordered, shipped, and installed on the radio tower in accordance with the wishes of the EcoTarium staff. The installer arrived at the site mid-morning and the device was installed by the end of the day. We offered assistance where warranted and the provided the installer with any information required. Once the device was installed, we connected it to a display in the museum for monitoring purposes and were instructed in its operation. The device was now operational and data collection could therefore begin.

3.1.5 – Data Monitoring and Staff Training

With the anemometer installed and collecting data, we began to monitor the data and determine the wind speed, direction, and consistency. We monitored the device ourselves for the duration of the project to get a better understanding of its operation and familiarize ourselves with the software. In addition, we instructed the EcoTarium staff in the operation of the anemometer and its software. This enabled the EcoTarium to continue the study independently and collect data after the conclusion of our project. Once, we had installed our anemometer and trained the staff to use it, we next recommended where to move forward with this wind project.

3.2 – Objective Two: Recommendations for Future Wind Studies

The EcoTarium also requested that we give them suggestions for a future wind turbine installation. They wanted to know what types of turbines are available and which ones would be most suitable for their campus. To give them this information, we researched and consulted with professionals about the installation of wind turbines. In addition, we consulted with EcoTarium staff regarding the uses of the turbine on their campus. We first needed to recommend how long they should collect wind data to determine if the wind strength justified turbine installation.

3.2.1 – Wind Study Duration

In order to collect an accurate range of wind data, recommendations were made as to how long data collection should continue. We spoke with the representative from SunWind about the duration of a preliminary wind study and we were given recommendations based upon the time of year and the area being studied. From this we were able to accurately recommend how long the data collection should carry on.

3.2.2 – Turbine Research

We needed to choose the most effective turbines for the museum. We defined “effective turbines” as a turbine the EcoTarium could use for an exhibit with power generation a secondary function. The EcoTarium preferred a small-scale device rather than one large enough to power their facility. Their desire was to have a wind turbine that their guests might be able to utilize at home, giving more of a take-home message (Pitcher, 2010). Thus our research focused on this point.

We utilized various sources to gather information on effective wind turbines. Several of these sources were online articles detailing basic information about residential wind turbines. More notably, we visited the Wind Lab atop the Boston Museum of Science (see Appendix H). The Wind Lab utilizes five different types of small wind turbines, making it a perfect point of interest. We took a visit to the lab to investigate, and while there, we interviewed its manager to get some more detailed information. In a more direct fashion, we also discussed possible future turbines with the company representatives we contacted. For example, we spoke with the representative from SunWind, who suggested that a 10 kW wind turbine may be feasible to install (See Appendix E). Finally, we searched through previous WPI IQP reports that dealt with wind feasibility studies to gain more information about wind turbine installations (see Appendix K). All of these various sources provided us with information that would help guide the EcoTarium in continuing this project.

3.2.3 – Biodiversity Factors

In addition to our research on turbines, we had a meeting with the EcoTarium staff about the effect of turbines on biodiversity. Though this marked a detour from our installation-specific research, it was important to note, and factor in, the effects a turbine might have on local birds. The museum had been netting birds as part of a study of migration patterns, which they believed might be important to discuss before installing a wind turbine. The museum was interested in extending this study to determine what effect the turbines had on local birds through their living conditions and the turbines effect on their populations.

With data gathered and all factors considered, we proposed our recommendations to the EcoTarium staff. We gave them a set of devices that we believed they should consider along with important information regarding the final installation of the wind turbine.

3.3 – Objective Three: Solar Installation Design

While we progressed with the wind anemometer installation, we also began the work for a solar panel installation. This helped fulfill the EcoTarium's desire for a solar panel system on their Apple Spice Junction building (see Literature Review 2.4). The end result would reduce their energy bills and serve as a renewable energy exhibit. We completed the initial stages preceding the installation to get the museum moving forward with their project. This section details what steps we took to provide a foundation for the future installation.

3.3.1 – Power Consumption of the Apple Spice Junction

In order to determine what types of systems would best suit the Apple Spice Junction, an assessment of its power consumption was conducted. We first took an inventory of the devices that were used in the building and their power ratings in volts and amperes. Using this information, we converted these ratings into kilowatt-hours (kWh) used per month based on their estimated usage time. This allowed us to estimate the total power consumption for the Apple Spice Junction per month. This unit of kWh per month was useful because it could then be compared to the researched power consumption for the average U.S. home. Next, based on future system options, we would have a guideline for the amount of power that could be installed to simulate a residential system.

3.3.2 – Site Visits and Assessment

We began by contacting companies involved in the solar power industry. Speaking with company representatives let us avoid losing time on installation details. We actively sought knowledgeable people who could handle the installation details and provide us with designs and estimates. We also sought multiple opinions to ensure we got the best results. Several of the people we contacted responded indicating their willingness to work with us.

Meetings were conducted with company representatives, where we discussed our needs and obtained estimates. Our discussions, along with a visit to the Apple Spice Junction building, gave our contacts a clearer picture of what type of system we needed. We spoke with them about designing a solar panel system to be both functional and a museum exhibit. Once they understood our project needs, they were able to give us preliminary system designs and installation cost estimates.

3.3.3 – Analysis of Options

With a set of estimates compiled, we analyzed our options to select the most appropriate. Keeping the needs of the EcoTarium in mind, we sought to select an option that balanced feasibility and productivity. We noted that a viable museum exhibit was our major goal. However, we factored in the EcoTarium's desire to power Apple Spice Junction entirely through solar energy. This led to somewhat of a detour.

A portion of our analysis was devoted to figuring out how the building's rather high energy requirements could be met through the new system. Investigation and calculation revealed that the Apple Spice Junction building consumed more power than could be feasibly generated by a solar panel array. However, it also revealed that power is used extremely inefficiently there. We found that reducing the consumption could allow a smaller solar panel array to meet the demand. This finding directly impacted our analysis and final choice.

From our analysis, we produced a set of recommendations for the EcoTarium to move forward. Our recommendations included the system design, estimated installation cost, company to perform the installation, and recommendation for reducing power consumption. With these key points detailed, the EcoTarium had enough information to be able to apply for grants and complete the installation of the solar panel system.

3.4 – Objective Four: Preliminary Design of a Solar Exhibit

With this objective, we provided the EcoTarium with preliminary ideas for use in future exhibit designs. The purpose of this objective was to provide the EcoTarium with a sense of direction in designing a solar renewable energy exhibit. In order to complete this objective, we conducted research on how other museums have displayed renewable technologies, brainstormed our own ideas, and reviewed them to our successful exhibit criteria. Before providing any recommendations however, we first conducted research on current renewable energy exhibits.

3.4.1 – Museum Research

In our first task, we researched current renewable energy exhibits. This allowed us to develop an understanding of how these energies have been integrated into museums. We first conducted research online to discover institutions that had solar energy exhibits. Some of these institutions included the Chicago Museum of Science and Industry, the Miami Science Museum, the Tech Museum in San Francisco, Fort Worth Museum of Science and History, Kohl Children's Museum, the Danish Museum of Electricity, the UK Science Museum, and Capital Exhibits. All of these institutions featured renewable energy exhibits and solar displays.

We next visited the Museum of Science in Boston in order to see some of these exhibits in person and observe how people interact with them (see Appendix H). At the museum, we spoke with staff about the exhibit development and prototyping process. This gave us a greater understanding of what works and doesn't work in exhibits. We also discussed what they had found to be successful and what was not during their development stages. We would next develop our own ideas based upon this research.

3.4.2 – Brainstorming Exhibit Ideas

After gaining insight into what types of solar energy exhibits exist today, we were able to use this research to brainstorm our own ideas. To do this we generated a chart to organize our conceptual ideas (see Figure 3). These ideas contained designs to relate solar power to a wide age group and demographic. The goal of our proposed exhibits was to leave museum guests with the understanding and the desire to implement renewable energy into their lives. In order to ensure our ideas were solid however, we next compared our exhibit ideas to the successful exhibit criteria developed in Section 2.3.

Figure 3: Wall space used for idea generation

3.4.3 – Reviewing to Successful Exhibit Criteria

Our proposed exhibits were reviewed to the criteria developed in Section 2.3 of our Background and Literature Review. These criteria determined if our designs were theoretically successful or not. The exhibits that displayed the best development of the criteria were improved further. Those that did not uphold the criteria were either revised or eliminated from consideration. In doing so, we edited our designs, so that they upheld the criteria for a successful, family-friendly exhibit. Our criteria however, would not be enough to evaluate our exhibits and feedback was next collected to gauge public interest in our design ideas.

3.4.4 – EcoTarium Feedback to Exhibit Concepts

In order to determine which of our criteria-reviewed ideas were plausible options, exhibit feedback was collected from the EcoTarium staff. We held a meeting with Alexander Goldowsky, head of exhibit design at the EcoTarium, to discuss the exhibit design process and how they decide what concepts to use. We also discussed our generated ideas with him to determine his initial opinions on them and what areas we might improve on.

This feedback, along with our criteria, helped us determine which design(s) would be the most successful and appealing to EcoTarium guests and the general public. Through this process we provided the EcoTarium with exhibit ideas in areas where they have never designed exhibits before. We provided recommendations on what types of exhibits have been successful and some new ideas that may not have been used before. The completion of this objective concluded our project work, which is summarized below.

3.5 – Summary of Methods

The goal of this project was to aid the EcoTarium in the preliminary design stages of their wind and solar energy projects and provide useful recommendations, enabling them to move forward with their proposed energy exhibits. Our objectives to reach this goal included conducting the preliminary steps to assess the feasibility of a wind installation, determining the best options for a solar installation, generating design ideas for a solar energy exhibit, and making recommendations so the EcoTarium can move forward with these projects. Several of these objectives progressed simultaneously and together they ensured the completion of our goal. These objectives were beneficial to meeting the goal of our project because they each provided a systematic approach to meeting our goal and provided the EcoTarium with the groundwork for the completion of these projects in the future.

4.0 – Results and Analysis

In this section, we discuss our final findings and products generated from this project. As discussed in our Methodology, we completed the installation of an anemometer to study the wind, made recommendations for the future wind study, obtained a design and estimate to install a solar panel system, and drafted ideas for possible renewable energy exhibits. We detail here the results of our work on each of these objectives and explain their significance to our project.

4.1 – Exhibit Design

Some of the most important work we did for this project was generating exhibit concepts. We generated concepts for exhibits that would directly address common public uncertainties with solar panel technology. The goal was to engage people in solar technology and to help them understand that it is a viable, beneficial source of energy. Towards this end, our exhibit concepts cover details from the technology, to the installation, to the financial benefits, and to the environmental impact. We have reviewed our concepts to our set of criteria in order to ensure that they will be effective in engaging the audience (see Section 2.3.1). The result of our work is a set of exhibit concepts with accompanying tables indicating which areas of public uncertainty they address and how exhibit criteria are met.

4.1.1 – Solar Panel System Display

Just outside the back entrance to the EcoTarium, in view of the Apple Spice Junction, guests will come upon a display that appears to be a solar panel mounted to the ground instead of a roof (see Figure 4). Upon further inspection, guests will discover that it is an informational display about the system they can see on the Apple Spice Junction roof. The display will be scaled to the size of a real solar panel and will contain the relevant system information in a way that guests can understand. The display could contain such information as:

- System size
- System type
- Power produced (related to home power use)
- Percent of energy bill that can be saved
- Components installed, such as the inverter, rack, and panel

This information can then be related to consumers, as the system installed on the Apple Spice Junction will be a

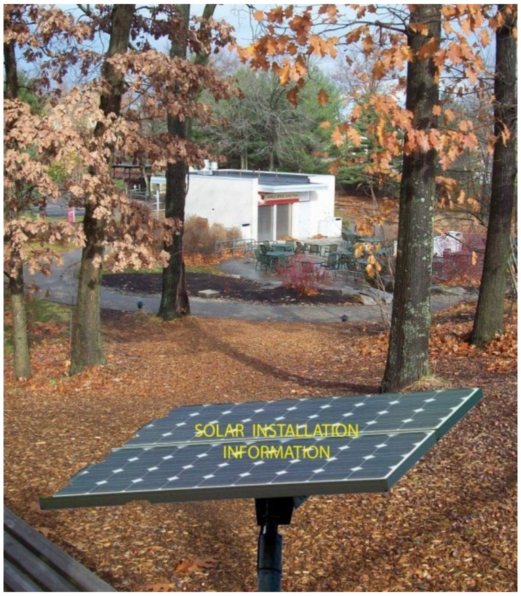


Figure 4: Mock-up of an informational solar display

residential-type application. With a better understanding of the technology and the direct financial benefits, guests may begin to see solar panels in a more positive light. Though they may not yet know the process for installing solar panels, this may prompt them to find out. It is important to note that this portion of the exhibit will be primarily for the older guests as it will be mostly text-based.

Our meeting with Alexander Goldowsky, the lead exhibit designer for the EcoTarium, revealed that text-based displays may not work as well in cases where children are present, as there is not much to interact with and they will want to leave quickly (Appendix C). With this in mind, interactive or eye-catching “accessory” exhibits could be added. For instance, small “flip-up” displays, similar to those in many child-oriented museums, could be placed near the display. These displays would act as a complement to the solar panel display by introducing basic facts about solar panel systems. It would provide children with information they can understand while adults can view the more in-depth solar panel display. Another possibility is to add a small solar panel or light detector next to the sign. Children would be prompted to cover the device with their hands and watch a light or meter react. Both of these methods would provide children with basic, understandable facts, as well as allow adults to garner information more relevant to them from the main display.

This exhibit design was next compared to the consumer uncertainties explained in Section 2.1.5 the criteria we developed in Section 2.3. Listed below is an explanation of the consumer uncertainties that this exhibit will address including the high initial investment, the lack of technical knowledge, and the lack of trusted references. The review to all of the successful exhibit criteria can be found in Table 3 below.

<u>High initial investment, with unclear return on investment</u>

This exhibit will be have factual information regarding the installed system at the EcoTarium as well as varying household installations. This information will address the initial cost along with the incentives used and the predicted return on investment. It will make it clear to the reader that though there may be a high initial investment, the system can pay for itself in less than a decade.

<u>Lack of knowledge regarding the equipment and its technological application and availability</u>

This display will replicate a solar panel, including the look, size, mounting rack, and inverter. This will be a replica of what is installed on the Apple Spice Junction so the guests can get an up-close look at the equipment and how it is installed on a roof.

Lack of trusted references from friends, neighbors, etc.

Guests will now have the EcoTarium as a major reference. They can garner information from displays or even talk to staff about the system. While the EcoTarium is obviously not as close to its guests as friends or neighbors, they are still a very noteworthy entity and can give advice on the matter if guests seek it.

Table 3: Exhibit Characteristics Included in the Main Solar Panel Display

Characteristic	Application in Exhibit
Multi-sided	Display is multi sided as many can view the replica
Multi-user	A few can read the text as others examine the replica
Accessible	It will be made at the average adult's waist height
Multi-outcome	Parents can relate information to their children
Multi-modal	Mainly focused for adults; accessory exhibits can remedy this
Readable	Large amount of text-based information
Relevant	In-depth information addressing common uncertainties

4.1.2 – Time Lapse Displays

Another exhibit would use time lapse displays to convey technical information as seen in Figure 5. One part of this exhibit would allow a user to seek through a video of the EcoTarium's actual solar panel installation. Utilizing a spin dial similar to many time lapse exhibits, a museum guest could watch an installation happening at their own pace, pausing and rewinding easily. At the end of the video will be close-up shots of the finished system to give guests a better visualization of it. Surrounding the video would be short text segments outlining the basic steps for a consumer to have a solar panel system installed. These segments, along with the video, would give guests a better understanding of the technology and the installation process.

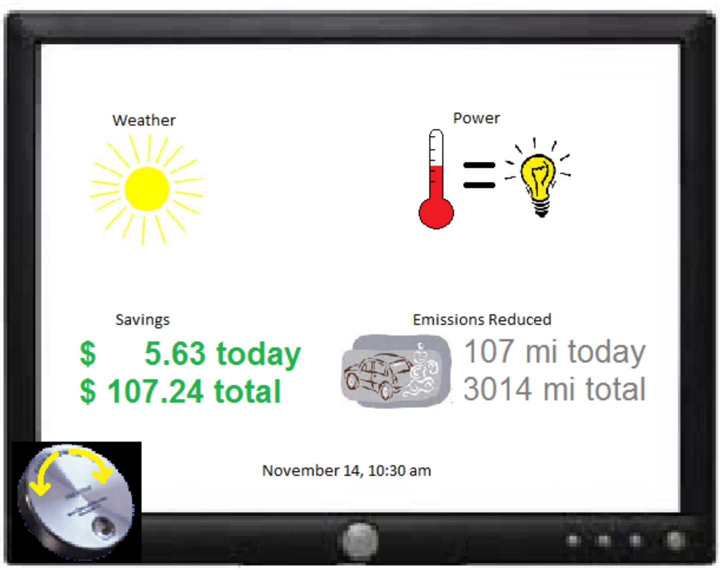


Figure 5: Example of a time lapse display

The other part of this exhibit would display the real-world power output of the solar panels. A spin dial would again be used, allowing the user to view the current power output of the panels as well as power output from various times in past days. Information displayed will include time of day, general weather conditions, and power output. This data will be “interpreted” and presented as more meaningful data, such as amount of money saved on electrical bills and carbon dioxide emissions reduced in terms of automobile emissions. In this way, guests can view authentic real-world solar panel power output, and they can gather basic facts about sunlight’s effect on power output and the benefits of using a solar panel system.

These technologically-oriented exhibits can give guests more understanding on the details of solar panel systems. They can learn the steps they need to take for an installation, learn information about the technology, visualize actual power output, and gather understandable data on the environmental and financial benefits the solar panels provide. Providing them with information such as this addresses several common concerns with the technology and can show them that it is a viable option for them. Guests will be able to understand and relate to the technology better, making them less wary about installing it, and they will see real-world benefits, which may entice them to adopt.

This exhibit design was next compared to the consumer uncertainties explained in Section 2.1.5 and the criteria we developed in Section 2.3. Listed below is an explanation of the consumer uncertainties that this exhibit will address including the high initial investment, the lack of technical knowledge, and the perception that an installation will be difficult. The review to all of the successful exhibit criteria can be found in Table 4below.

A perception that the installation processing is difficult and complicated

Guests will be able to see the ease of installation through the video, which they can seek through at their own pace. It will provide them with the steps they take, which are contacting an installer and having them perform a site evaluation, and also informs them of how an actual installation works.

Lack of knowledge regarding the equipment and its technological application and availability

Equipment is shown in the installation video, and the technology is covered by the power output display. Guests can feel more comfortable with the technology after being given basic facts about the equipment and its usefulness.

High initial investment, with unclear return on investment

Actual money saved by the solar panel systems will be provided. They may also provide an estimated return on investment timeframe, which will directly address this concern.

Difficulty in finding a qualified installer

While not a comprehensive list of installers, the EcoTarium can provide guests with information about the company that installs their solar panels.

Table 4: Exhibit Characteristics Included in the Time Lapse Displays

Characteristic	Application in Exhibit
Multi-sided	Can be viewed by two families at a time
Multi-user	Only one person can interact with each portion of the exhibit
Accessible	Children can easily reach the controls for the exhibits
Multi-outcome	In-depth information can allow multiple opinions on feasibility
Multi-modal	Mostly facts for adults, but kids can turn dials and watch effect
Readable	Textual data is interpreted and presented in meaningful format
Relevant	Real-world examples addressing common concerns

4.1.3 – Solar Playhouse

This exhibit, which is geared more for children, utilizes a model house and a moveable light to illustrate the function of solar panels (see Figure 6). The light will have a handle, allowing guests to move the light from one side of the house to the other, simulating the sun. It will also have a slider that allows the guests to dim the light, simulating cloudy days. On the house will be a small solar panel, or a model of a solar panel system, with a sunlight intensity sensor. When light is shone on the panels, various appliances inside of the house will be lit up with LEDs. Appliances, such as a light bulb, a computer, a TV and a refrigerator, will be lit up as the solar panel "produces" enough power. This will illustrate that solar panels produce different amounts of power depending on the amount of sunlight they receive. It will also show children that solar panels can power everyday appliances.

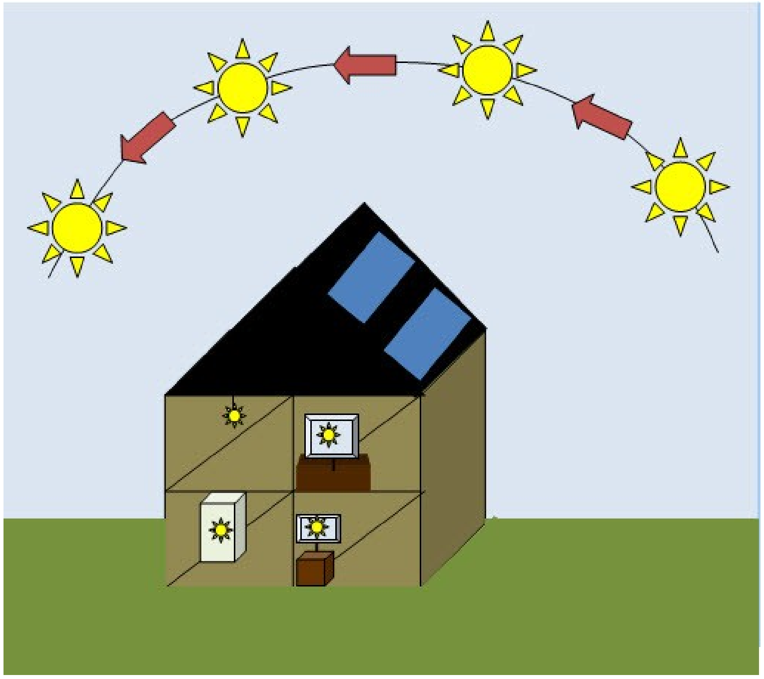


Figure 6: Mock-up of a solar playhouse concept

A complementary display would provide guests with more information and expand the exhibit. This display would indicate the current amount of energy being "produced" by the model solar panel as well as the amount of power needed by the various home appliances. Following this, a text prompt will challenge the user to try and power all devices and find out when the most power is generated, helping them become engaged with the exhibit. The display would also include meters indicating the amount of money currently being "saved" by the model solar panels and the amount of waste emissions reduced. This will be presented in more meaningful ways for children, such as a growing and shrinking dollar bill to represent the savings and pictures of automobiles to represent emissions. This will make the exhibit more of an engaging game for children as well as provide adults with simulated financial information.

While this exhibit is simple in content, it still provides important information for both children and adults as it adheres to the criteria for a successful family exhibit (see Table 5). It introduces guests to the fact that solar panels can power home appliances. It also teaches them through interaction that weather conditions affect power output. The accompanying display also provides guests with the simulated financial and environmental benefits of solar panels. All of this helps children understand what solar panels are and how they help the world, and it even touches upon some of adults' concerns with renewable energy technology as listed below.

Lack of knowledge regarding the equipment and its technological application and availability

This exhibit contains an interactive model that relays the amount of power generated from an average homeowner solar panel installation. It relates the power generated to what it appliance it could run.

High initial investment, with unclear return on investment

Simulated financial benefits are provided, giving an indicator of how much a guests could save if they utilized solar panels.

Table 5: Exhibit Characteristics Included in the Solar House Exhibit

Characteristic	Application in Exhibit
Multi-sided	Exhibit is out in the open, displays are in plain view
Multi-user	Only one person can interact with the exhibit
Accessible	All age groups can interact with the exhibit
Multi-outcome	Parents can talk to and teach children about environmental effects
Multi-modal	Basic facts for children and some details for adults
Readable	Large text and short sentences form the displays
Relevant	Basic information addressing solar power uses

4.1.4 – Fossil Fuel vs. Renewable Energy Trail

This exhibit was designed to address less of the uncertainties and more of the background concepts behind renewable energy. While this does not directly address our major project goal of helping people adopt, the necessity of renewable energy is a major theme in our project and we believe it is important to relate it to museum guests. It was addressed somewhat in our other exhibit concepts, but this exhibit will directly address it through messages such as: *there are many sources of energy (Non-renewable and Renewable)*, *non-renewable energy sources produce waste/byproducts that are harmful to our environment*, and *our choices of our energy sources do have an impact on our environment.* The exhibit would serve to inform guests, mainly children, about renewable energy and excite them to learn more.

Our exhibit write-up, located in Appendix I, discusses all components of our concept design. For the purpose of avoiding repetition, only one of the interactive components will be discussed here: the Renewable Energy Ball Pit (see Figure 7). The pit contains colored plastic balls to indicate types of energy, such as a yellow ball for solar energy and a white ball for wind energy. The exhibit concept utilizes these plastic balls to create a game for children to learn the environmental impact of different sources of energy.

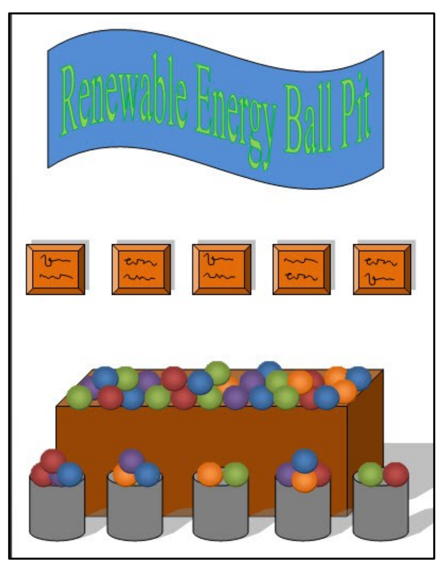


Figure 7: Renewable energy ball pit concept

Children would be prompted to collect balls from the pit with the help of adults and bring them to a nearby station containing baskets. Each basket would allow for 5 balls to be placed in it. After a combination of 5 balls had been collected, there would be a corresponding reading and display output that would explain the environmental impact the energy combination would have. Here the adult could explain to the child that his or her choices had consequences on the future environment and try to help them collect a combination for a cleaner future. An explanation of the criteria this exhibit adheres to can be found in Table 6 below.

Table 6: Exhibit Characteristics Included in the Fossil Fuel vs. Renewable Energy Trail Exhibit

Characteristic	Application in Exhibit
Multi-sided	This exhibit allows the interaction of an entire family or group
Multi-user	Both portions allow multiple user interaction
Accessible	Children can easily collect the balls, adults can provide assistance
Multi-outcome	Adults can explain to children the outcome of their choices
Multi-modal	Children can play and learn basic concepts with the help of adults
Readable	The few displays in the exhibits contain easily readable text
Relevant	Adults can see the future effects of their past energy choices

4.1.5 - Solar Pamphlet

We determined that in order to create interactive family exhibits based on solar technology, the information had to remain brief while still relaying the major topics. We also wanted the ability to target not just the family as a whole, but the adults who have the ability to adopt solar technology. Since the major goal of our project was to help people adopt renewable energy technology, we felt it was important to provide more in-depth information.

The major idea we developed was to produce a solar technology pamphlet to place near the solar exhibits and the information desk. The pamphlet would be text-based and target homeowners with information relevant to adopting solar energy. It would contain technological information, financial and environmental facts, steps to take for an installation, and a list of available local solar installers. This information would directly address all of the common uncertainties with solar technology. The main idea behind the pamphlet was thus to create something interested museum guests could take home and read to better understand the technology and to learn how to adopt it.

4.1.6 – Wind Data Sheet

Another option that helped convey more adult-targeted information to guests was a handout about wind energy for the homeowner. We wanted a more text-based poster to convey information that would be pertinent to the possible installation of a household wind turbine. We decided on making a poster so that an exhibit based around wind technology could be more family oriented, less text-based, and more fun in general. The mock-up of the poster can be seen in Appendix J and it includes general information regarding residential sized wind turbines.

4.1.7 – Final Notes on Exhibit Concepts

The results of our work on exhibit design are several concepts ranging in information and interactivity. We covered many main project topics from the major background themes behind our project to the public concerns with renewable energy technology. We also ensured that our concepts were sound in theory by reviewing them to our exhibit criteria. Though no one exhibit covers all topics and satisfies all criteria, as a whole, we believe they are comprehensive and effective. We still note that these are only preliminary concepts and that the EcoTarium's own exhibit staff will need to review them. They are much more experienced and may find and work through issues in the designs or implementations. Our concepts are intended to be a foundation for the EcoTarium to build off of and to use as a springboard for future exhibit ideas.

4.2 – Solar Panel Installation

We were able to select and recommend a solar panel system that would be practical for the EcoTarium. Our decision was made from a three-step process, which involved visualizing the ideal system, gathering available system options, and assessing feedback from the EcoTarium staff. Following this process allowed us to narrow our search according to the needs of the project. The concept for the ideal system specified which systems to consider from the available options, and the staff feedback allowed us to make a final decision.

4.2.1 – The Ideal System

The ideal solar panel system for the EcoTarium would be a residential-sized (2-4 kW) photovoltaic installation. A major factor in determining this system was ease-of-use in a museum exhibit. A 2-4 kW size range is the average for residential installations, which allows us to relate it to museum guests by showing the size that would be installed on their own home. In addition, the power output of the system can easily be monitored and therefore be included in an exhibit display, such as the Time Lapse Exhibit discussed in Section 4.1.2 and Appendix I.

The other major factor was usability of energy output. Electricity formed from a photovoltaic system could be routed to main EcoTarium facilities when the Apple Spice Junction building is not in use. Similar functionality is not available with solar thermal systems which can only provide hot water to the building they are installed on. In order to ensure that the EcoTarium could most effectively utilize the system that they pay for, we decided to focus only on photovoltaic.

We had originally planned to power the entire Apple Spice Junction building with the solar panels. Unfortunately, our inspection of the Apple Spice Junction building had revealed that its energy demand could not easily be satisfied by even the largest feasible photovoltaic system for the site. Rough calculations had put electricity usage at over 1000 kWh per month, whereas a 4 kW photovoltaic array would provide only 500 kWh. As such, the energy demand of the building became less important to our decision and was not factored into the ideal system.

4.2.2 – Proposals and Estimates

In order to ensure we completed our work before our deadline, we contacted solar power companies both during and after framing the ideal system. Due to this, the estimates we received were not always within the ideal system size range. We were able to compare the estimates by calculating the cost per Watt installed and scaling that to estimate various system sizes (see Table 7). Estimates we obtained came from three companies: Advanced Energy Systems, New England Breeze, and SunWind.

Table 7: Installation Prices for Solar Photovoltaic Systems as Quoted

Company Name:	Proposed System Size:	Cost of System:	$/watt installed:
Advanced Energy Systems	1.6kW	$20,787.35	$12.99/watt
New England Breeze	4kW	$32,000	$8.00/watt
New England Breeze	2kW	$16,000	$8.00/watt
SunWind LLc.	5.06kW	$32,000	$6.32/watt
SunWind LLc.	2.53kW	$17,575	$6.94/watt

AES came to the EcoTarium to assess the site before drawing up possible system designs. They provided us with a relatively positive affirmation of the feasibility of a solar panel system, and they gave us proposals and estimates for both a 1.6 kW photovoltaic system and a two-panel thermal hot water system. Though we gained insight into the possibilities and limitations of the project from this visit, we found that the final proposals were rather expensive. The estimate for the photovoltaic system cost approximately $12. per Watt installed, while the average cost for an installation is between $7-9.

New England Breeze did not visit the site, providing only a projected estimate of installation costs. Their estimate, however, was very reasonable. The projected price for a photovoltaic system was $7-7.50 per Watt installed, which is less expensive than Advanced Energy Systems' proposal and fits in the average range of costs. They also provided a more favorable estimate for a solar thermal system than AES. Both companies estimated $10,000 for a solar thermal system, but New England Breeze would provide a larger system for the price.

Finally, SunWind provided us with two estimates for solar photovoltaic systems. Both estimates included optional roofing enclosures to make the system appear as it would on the roof of a home. One estimate was for a 5 kW system which, while out of the ideal system range, was noted for its price. The total installed cost was an acceptable $7 per Watt installed, which is an average cost, and by deducting optional components and private incentives, it was reduced to $5.80, substantially cheaper than the average cost. The other estimate, for a 2.5 kW system, was priced similarly. The total installed cost was approximately $8 per Watt installed, which lies in the average range of costs, and by deducting optional components and private incentives, this was reduced to $6.40, also cheaper than the average. In addition, we noted that this proposal cost a total of $20000, which is the same price Advanced Energy Systems gave us for a much smaller installation.

4.2.3 – Choosing a System

Our initial choice is for the 2.5 kW proposal from SunWind. For the price, they provide better value than Advanced Energy Systems and at least equal value with New England Breeze. They have also made a site visit, which makes their proposal more reliable than the projected prices from New England Breeze. We chose the 2.5 kW proposal instead of the 5 kW due to the fact that a 2.5 kW system falls into the average residential range, and hence our ideal system range. However, before we can make a final decision, we must discuss the options with the EcoTarium staff and gather their opinions.

4.3 –Anemometer Installation

We completed the installation of an anemometer to measure wind for a future wind turbine installation. We gathered wind data, available options, and staff opinions in order to ensure that we provided the EcoTarium with a suitable system.

Basic research on wind maps provided by the Massachusetts Geographic Information System revealed that the possibility of adequate wind speeds was very likely. The maps displayed the area around the EcoTarium in a 6-7 m/s average wind speed range (see Appendix D), and many small turbines require only 5 m/s to operate effectively (Holmes, 2010). With this promising initial data, we believed it was worthwhile to move forward with the anemometer installation.

We contacted several companies and were able to set up site visits and get cost estimates (see Appendix E). The companies that gave us system proposals and estimates were AES and SunWind. SunWind gave us two estimates, both of which we felt provided more value for the price than the proposal from AES. We came to this conclusion due to several factors. First, SunWind provided lower costs; they made it clear that they did not markup the price of their anemometer parts, and they provided much lower installation costs. In addition, both of SunWind's proposals contained more features than the AES proposal. Of the two SunWind proposals, we felt the Davis Instruments Vantage Pro 2 anemometer system was the better choice (Appendix E). It provided a multitude of extra features, most notably wireless network data logging, for a very minimal price increase over the other proposal (Appendix E).

Our final decision was for the Davis Instruments proposal, which we based on discussion with the EcoTarium staff (See Figure 8). This discussion came about as part of a "progress report" presentation focused on the anemometers. Following the presentation, the EcoTarium staff gave us their thoughts on the matter, in which it was clear that they favored the Davis Instruments system from SunWind. The staff members who seemed most familiar with anemometers all spoke highly of the Davis Instruments company. In addition, they revealed that they had plans for a secondary exhibit for which they could use the anemometer. This concept exhibit, which involved weather conditions, could make great use of the extra features provided by the Davis Instruments anemometer. With unanimous favor for this system, we finalized the transaction with SunWind.

Figure 8: The Davis Instruments Vantage Pro II (top &bottom right) and the EcoTarium's radio tower after installation (left)
(Image credit: Davis Instruments)

Once the anemometer had been installed, we learned how to use the data logging system and provided the EcoTarium with a short, concise tutorial sheet (see Appendix F). With our work completed, the EcoTarium was left with a working anemometer system and the knowledge to utilize it. They could now complete the full wind study themselves upon the completion of our project. As such, we have successfully begun their project for a wind turbine exhibit.

4.4 – Recommendations for a Future Wind Study

Complementing our work on the anemometer installation, we provided recommendations for the future wind study. These included wind study instructions, possible turbine options, and secondary uses for the turbine. While these are all separate points, we believe that each piece of information could be useful as the EcoTarium moves forward with the project. Each piece of information we provided serves to guide the Museum before, during, and after a wind turbine installation.

Most important of our recommendations were reference materials that would direct the EcoTarium as they perform their wind study. These included past IQP reports where wind studies were the major focus. Relevant information from the reports, such as a timeline for conduction a wind study and methods for analyzing the data are necessary for the EcoTarium to be able to effectively use their anemometer (See Appendix K).

To provide the EcoTarium with some of the ground work to move forward, under the assumption that the wind will prove feasible, we researched some of the available turbine options. This research revealed that there are both vertical and horizontal axis turbines (see Figure 9), both of which have pros and cons. For example, horizontal axis turbines, the most widely known type, have currently been made into much larger sizes, but are dependent upon a fixed wind direction. The vertical axis ones however, are independent of wind direction, but are currently smaller scale and have smaller market.

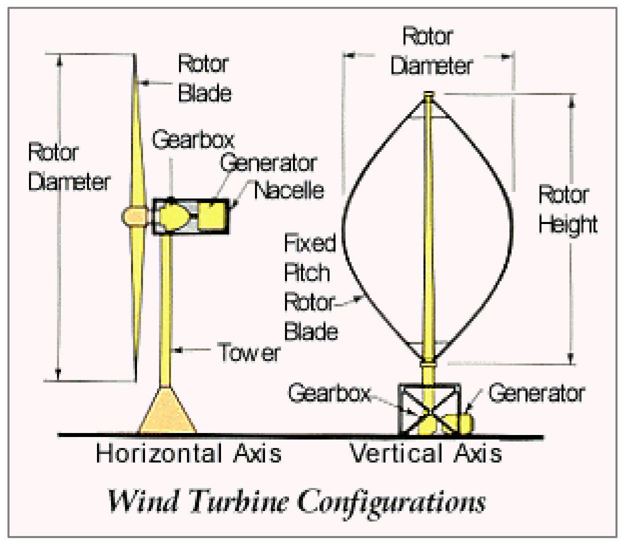


Figure 9: The two types of wind turbines.
(Image credit: http://www.changetorenewables.com/)

In addition, we proposed feasible turbine sizes based on interviews with Timothy Holmes from SunWind (Appendix E). He believed that the EcoTarium should not have a problem installing a 4 kW turbine on their tower, and that they could likely install a 10 kW turbine if some minor maintenance was performed on the tower. We noted, however, that these were merely initial opinions and that a structural engineer would need to assess the stability of the tower before any decision on system size is made.

Finally, we recommended that the EcoTarium utilize their turbine for research on bird and bat collisions. Insight into this potential research came from a meeting with the EcoTarium staff about the

Museum's current bird studies. We discussed the tagging and data logging on local birds and proposed an expansion into the relatively unexplored area of bird and bat turbine collisions. This could reveal new information on the safety or dangers of residential wind turbines on local avian wildlife. It may also provide the EcoTarium with the opportunity for research-based grants to cover the cost of the turbine installation. As such, we recommended looking further into the bird and bat studies.

4.5 – Results Summary

Our work has resulted in strong foundations and recommendations for wind turbine and solar panel installations along with comprehensive designs for solar power exhibits. We feel that we have designed exhibits that can effectively give museum guests information on solar panel technology. While each exhibit upholds the various characteristics at different degrees, all of them together cover the characteristics well. In the same way, all of the exhibits together address each of the common uncertainties that we discussed. Viewed as parts of an overall system, we believe they satisfy our goal of providing engaging exhibits that educate guests on renewable energy. However, we do acknowledge that these are merely concepts and have not been tested. It is possible that testing may reveal weak or ineffective points in our designs. As such, we present these concepts as a starting block for moving forward with the solar exhibit design. On the other hand, we have an anemometer installed, a final decision for a solar panel system, and recommendations for a future wind study that the EcoTarium can begin to use immediately. As such, the foundations for future wind and solar exhibits have been laid. The EcoTarium can now take our work and begin to shape an informational showcase of renewable energy technology.

5.0 – Conclusion

The EcoTarium has a unique position as an informal learning center. Picking up where school curriculum leaves off, they try to encourage lifelong learning through interactive and engaging exhibits. The EcoTarium also acts as a trusted source of information to the local communities. Using this community role, the EcoTarium aspires to help educate their guests about renewable energy technologies. They seek to help guests understand the necessary changes to our energy infrastructure through a showcase of renewable energy technologies and subsequent educational exhibits explaining them. This project helped the EcoTarium realize this goal by determining the appropriate technological installations and how those technologies could be turned into interactive family exhibits. The ultimate goal of this project and the goal of the EcoTarium was to help guests understand, accept and adopt renewable energy technology.

After completing research and conducting interviews with installers, were able to recommend a PV solar array and a reputable installer. We came to the conclusion that the best system for the EcoTarium would be a residential size system that a homeowner could install on their house. We recommended a 2-4 kW system from SunWind, LLC due to their reasonable pricing, the exhibitability of a display, and overall customer service. This will help guests better relate to an installed system as they can see the size system they would need, understand how it is installed, and see how much electricity can be produced. To help the EcoTarium move forward with showcasing solar technologies we also recommended several exhibit ideas for solar power. These ideas will help incorporate solar energy technologies into their current exhibits in an interactive way, engaging guests to learn more about renewable energy.

We also aided the EcoTarium in the future installation of wind power. After research and site visits from Advanced Energy Systems and SunWind we recommended the installation of a wind anemometer to the EcoTarium staff to measure wind data for a future wind feasibility study. After finding funding for the anemometer the device was installed at the end of our seven week project. Along with the anemometer we left behind a user guide for the anemometer describing how to collect the data, how long to collect data, and how to use the collected data (See Appendix F). We also researched a few different residential size wind turbines that could be optimized at their campus.

The EcoTarium understands that there is a problem with fossil fuels and is concerned about the uncertainty of what is to come without the transition to renewable technology. They want to use the unique role they have in the community as a learning center and trusted friend to show people that the transition to renewable energy is possible. The EcoTarium understands the uncertainties of adopting renewable energy technologies and is committed to helping their guest overcome them. Our project has thus helped the EcoTarium continue to educate the public and serve as a place for all ages and demographics. From our work, they will be able to continue helping people interactively understand, accept, and adopt renewable energy technologies to promote a cleaner, greener energy future.

References

AltE. (n.d.). *Introduction to Solar Electricity*. Retrieved November 4, 2010, from: http://www.altestore.com/howto/Getting-Started-Renewable-Energy-Sustainable-Living/Introduction-to-Solar-Electricity/a89/

American Recovery and Reinvestment Act of 2009. Retrieved 09/02, 2010, from: http://readthestimulus.org/hr1_final.pdf

Borun, M., Dritsas, J., & Johnson, J. (1998). *Family learning in museums : The PISEC perspective*.

Bradford, T. (2006). Tools for Acceleration. In *Solar Revolution: The Economic Transformation of the Global Energy Industry* (pp. 171-184). Cambridge, MA: MIT Press.

Carless, J. (1993). *Renewable Energy.* Walker Publishing Company, Inc.

Cronk, S., & Esternon, L. (2002). *Solar 2002 Conference: Renewable Energy Consumer Education Program for California*, Energy Matters LLC. Retrieved November 19, 2010, from: http://energymatters.net/pubs/rece.pdf

Cool Flat Roof - IB PVC flat roofs and Metal Roofing installation in Massachusetts (2009, June 18th). *Solar PV Guide: Prices, Design, Installation & Pay-off Period*. Retrieved November 19th, 2010, from: http://www.coolflatroof.com/solar-power-guide.php

DeFusco, D. (2005). *Yale Poll Reveals Overwhelming Public Desire for New Energy Direction*, EurekAlert. Retrieved October 7th, 2010, from: http://www.eurekalert.org/pub_releases/2005-06/yu-ypr060905.php

EcoTarium: A Museum of Science and Nature (2009). Retrieved from: *http://www.ecotarium.org/*

Green Energy Ohio (n.d.). *Steps to Installing a Wind Turbine.* Retrieved November 23, 2010, from: http://www.greenenergyohio.org/page.cfm?pageID=2229

Hein, G. (1998). *Learning in the Museum* Routledge.

Hirsch, R. L. (2005). *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management* (pp. 64-65). Retrieved 09/02, 2010 from: http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

Holmes, T. (2010, November 9). Personal Interview.

How Much of Our Electricity is Generated from Renewable Sources? (2010). Retrieved October 7th, 2010, from: http://www.eia.doe.gov/energy_in_brief/renewable_energy.cfm.

Kelly, T. (2009, April 28). *Where Wind Turbine Generators Work Best: Wind Power Generation for Homes, Business and Industry*. Retrieved November 24, 2010, from http://www.suite101.com/content/small-wind-turbines-how-to-assess-locations-a113364

Manwell, J.F. (2002). *Wind Energy Explained: Theory, Design and Application*. Chichester, NY: Wiley.

Pitcher, S. (2010, September 12). Personal interview.

Premier Power Renewable Energy, Inc. (2010). *Net Metering: Sell Your Solar Energy*. Retrieved November 23, 2010, from: http://www.premierpower.com/solar_energy_residential/free_electricity_net_metering.php

Quaschning, V. (2005). *Understanding Renewable Energy Systems* Earthscan.

Rowe, M. (2010). *When Will the Oil Flow Slow?* Retrieved from: http://find.galegroup.com/

Sawin, J. L. (2009a). Another Sunny Year for Solar Power. In *Vital Signs - 2009* (pp. 38-40). Washington, DC: Worldwatch Institute.

Sawin, J. L. (2009b). Wind Power Continues Rapid Rise. In *Vital Signs - 2009* (pp. 32-33). Washington. DC: Worldwatch Institute.

Solar Development, Inc (2007). Solar Energy Fact Sheets. Retrieved November 21, 2010, from: http://www.solardev.com/SEIA-sunshinehomes.php

Tester, J. W., Drake, E. M., Driscoll, M. J., Golay, M. W., & Peters, W. A. (2005). *Sustainable Energy: Choosing Among Options.* MIT Press.

U.S. Bureau of the Census (1996, May). *Projections of Households by Type: 1995 to 2010*. Retrieved November 21, 2010, from: http://www.census.gov/population/projections/nation/hh-fam/table1n.txt

U.S. Department of Energy (n.d.). *Solar Water Heaters*. Retrieved November4, 2010, from http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850

Veverka, J. A. (1998). *Interpretive Master Planning: The Essential Planning Guide for Interpretive Centers, Parks, Self-Guided Trails, Historic Sites, Zoos, Exhibits & Programs*. Acorn Group.

*Worcester (city) QuickFacts from the US Census Bureau (census data) (*2000). Retrieved from http://quickfacts.census.gov

Appendix A: Interview with Steve Pitcher

9/9/2010

Notes from a meeting with Steve Pitcher, President of the EcoTarium

Background Information

- The EcoTarium was established in 1825 and is the 2nd oldest of its kind in the country
- They moved to their current location in 1971 and have 60 acres of land available.
- Have had many name changes and are officially known as the Worcester National History Society

Guests

- Aimed at targeting families with kids
- Schools will deal with the formal education and they will deal with the informal education
- Performed a survey and discovered that 20%-30% of the current teachers in Worcester were sparked by the EcoTarium to pursue such a career.

Reinventing the EcoTarium

- About both the physical and natural sciences
- Have about 130,000 visitors per year
    - 30,000 being school kids
- $4 million budget

How to Keep the Guests Engaged

- Only about 15% of guests come from more than 15 miles away
- Guests say they like it there, but want to see new things when they come
    - Don't want to see the same exhibits every time they come
    - Interaction is key, less formal than direct instruction, informal learning

Partnering with WPI

- Use our talents to help them provide a learning experience for the guests

Remodeling the EcoTarium

- Want to raise roughly $35 million
- Have an $8 million funding
- Entering the 3rd century of the EcoTarium
- IMLS Grant for redesigning the building
- Start remodeling in roughly in 9 months
- Want to take advantage of the floors
    - Different themes for each floor
    - Top floor would mountains/urban
    - Middle floor would be forest
    - Bottom floor would be water

Urban (at least one year away)

- Part of this could be aimed at the Worcester community for people that have apartments and how they can use renewable energy to their benefits
- Could display something about fire protection

Energy Trail

- Have different renewable energy technologies on this trail
- Demonstration installations
- Have a high point (possible wind turbine)
    - Need site study
    - Possibility of saying this is what you would need to power your house
    - Impact on birds

- Run during the night and day or?
- Site for solar energy/heating water possibility with it
- Can't choose too much to exhibit
    - Have to focus on the essentials
- Need to find funding for all of it

Educational Challenge

- Have activities for a range of ages
- Research: What can be one to achieve this
- How do you make it interesting?

Schedule

- Work on both urban and energy trail exhibits
- How to start these exhibits
- How to make your living space more energy efficient
    - Kids start learning at an early age
    - How to inspire them/spark interest
    - Interactive exhibits
    - Help students pursue a career in the science/technology fields
    - Teach people how energy works and where it comes from an how it works
- Work 40 hours a week
- Other IQP Projects have been done here
    - Want to actually implement what we do to make a difference
- Mary Martin (Contact to setup meetings)
    - 508.929.2783
- Will have a pass code for the gate
    - Parking on the left near the tent for employees
- Betsey Maloney is our on the ground contact person
- Have a sign in/sign out book
    - Possible time cards
- Will be volunteer hours
- Record all hours spent on project starting now
- Divide time between both exhibits

Proposal

- What can we do?
- What to focus on to accomplish?
- In depth planning
- Possible grant proposals for the exhibit
    - The costs, plan, how, and why it works and should be funded
- Cannot wait 3 years for the money
    - Need to make moves now

Appendix B: Interview with Timothy Holmes

Notes from two meetings with Timothy Holmes, President of SunWind, LLC

11/11/10

- The average wind study should cover at least 12- 15 months as the wind varies throughout each season and this will provide accurate data for moving forward with investing in a wind turbine
- The proposed tower for the anemometer installation is in an ideal location as it is about 90 - 100 feet tall and is about 30 - 40 feet above any obstructions
- The proposed tower also appears to strong enough to support up to a 10kW wind turbine, but may need a few cross members replaced, which would be determined by the inspection of a Structural Engineer.
- In the event of being able to use the existing tower for a wind turbine, it could save the EcoTarium up to $20,000.
- The EcoTarium being constructed of concrete may pose some issues when positioning the wireless receiver for the wind anemometer inside
- There might be some extra electrical wiring needed to power the wind anemometer, pending the status of the power box at the bottom of the tower and whether or not it is active

11/24/10

- To perform the site assessment of the Apple Spice Junction, Tim Holmes, used a camera that took a series of seven pictures over a panoramic view which would later be used to determine the amount of sunlight year round when coupled with a computer program
- The Apple Spice Junction does have the available roof size to support a 2kW - 4kW solar PV system
- Tim Holmes mentioned that he would design a system to our specifications that would also resemble what it would like on the common home
- One of the biggest obstacles regarding the adoption of renewable technologies is the lack of advertising
- To further make the installation look like a home, Tim Holmes, mentioned that a company, CityScape, makes roof covers for the pipes and exhaust vents on top of the Apple Spice Junction

Appendix C: Interview with Alexander Goldowsky

12/3/2010

We held a meeting with Alexander Goldowsky, head of exhibit design at the EcoTarium to discuss their exhibit design process and gain some feedback on our conceptual ideas.

- Overall we have two types of exhibits (1) premade traveling exhibits (2) in-house designed
- The indoor master plan guides what ideas the exhibits will be based upon; in the third century plan there are 4 concepts: water, mountains, forest, and urban
- We do some beginning research to gain some background knowledge in hopes of finding some literature on what others have done. Maybe others have done evaluations or reports on the subject so we won't have to do a front end evaluation.
- We tend to start with a survey to start to get a general idea on what would be effective
- In the beginning it is a lot of going back and forth between brainstorming then going to the floor and the intended audiences to get feedback on the preliminary ideas to see if the exhibit would be worthwhile.
- We then start morphing our ideas into specific ideas that could be implemented into the master plan themes.
- We then take those specific ideas to the floor of the center and ask people what they think on the ideas to see what we should add or take away from the proposed ideas.
- Then we go into prototyping of the important concepts. If it is an interactive exhibit then it needs to be prototyped with working parts. You never know how people will interact with it until it's tested with the audience. Also texts, fonts, and concepts are also prototyped to see if the audience understands the exhibit and if the main message comes across the way we intend it to.
- There is always some level of change in the prototyping stage. One exhibit idea can go through the prototyping stage multiple times; this is where many exhibits get scratched and where many are developed.
- Prototypes are built out of whatever we have around the shop, sometimes out of cardboard; it's just to get idea of the final design.
- After prototyping we get a final list of exhibits and where they go within the themed areas.
- We get the final text written, then get an exhibit designer to build the exhibit and a graphic designer to make everything look nice

- Then installation…

Comments on our brainstormed exhibit designs for solar technology:
(see Appendix I for concept ideas)

Time Lapse:

How does the spin wheel of the installation address the installation phobia? How will it help them get over that phobia? How much of the install do you put on it? From signing the contract…? It will depend on how the guests understand it. It should work with the visitor it should somehow tie back to another exhibit. Money is a lot more meaningful. Put in monetary examples or relate it to money. You have to think about the problem which is payback period then how does the data you want to show address the payback period.

Renewable Energy vs. Fossil Fuel Trail

There should like a cell phone device or sheet of paper to keep **continuity** and keep the message going. Try and connect other exhibits with it using the paper there needs to be continuity. Maybe make some kind of game out of it.

Appendix D: Massachusetts Wind Maps

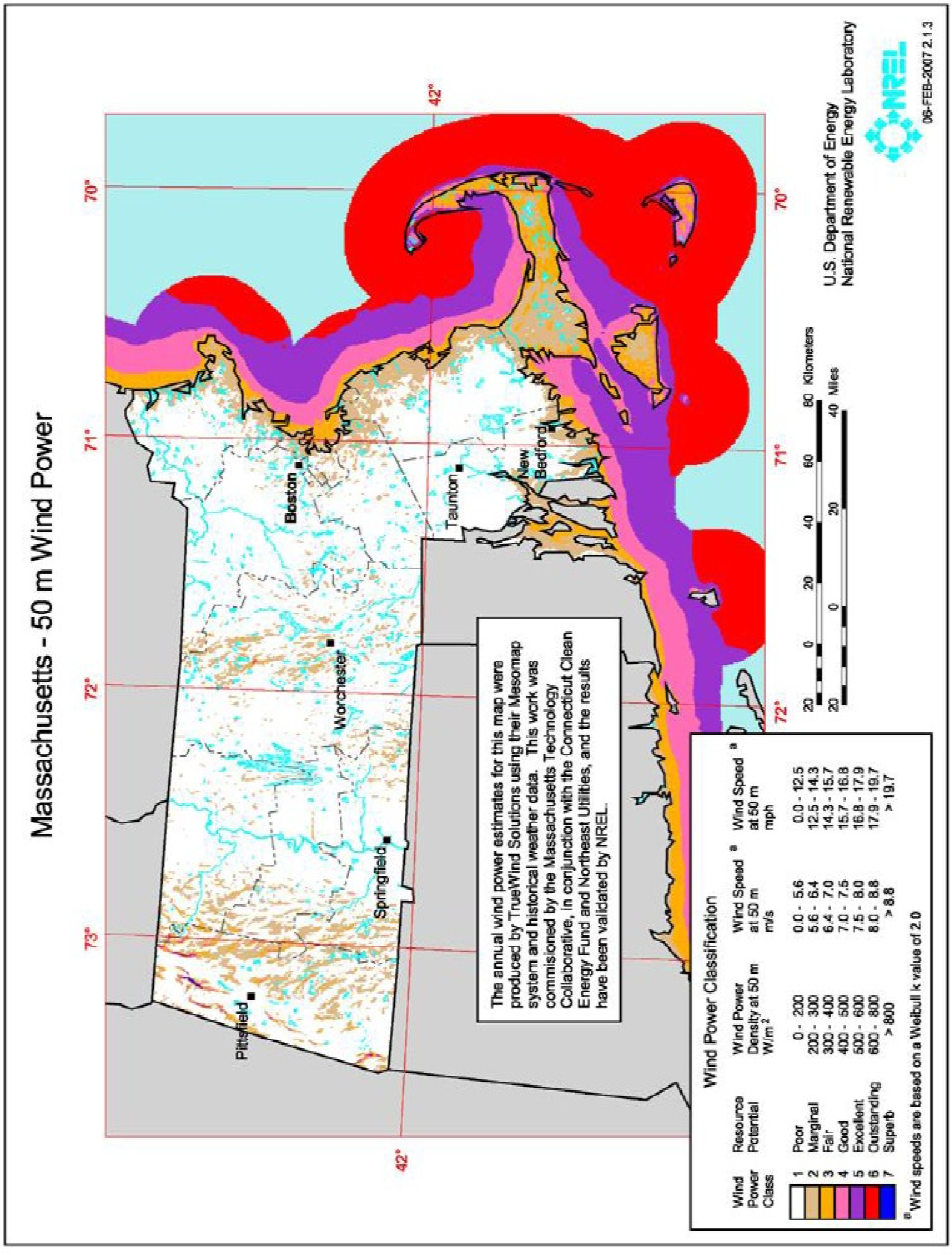


Figure 1: Massachusetts Wind Resource Map at 50 Meters Above the Ground

(Energy Efficiency & Renewable Energy: Wind Powering America, 2010)

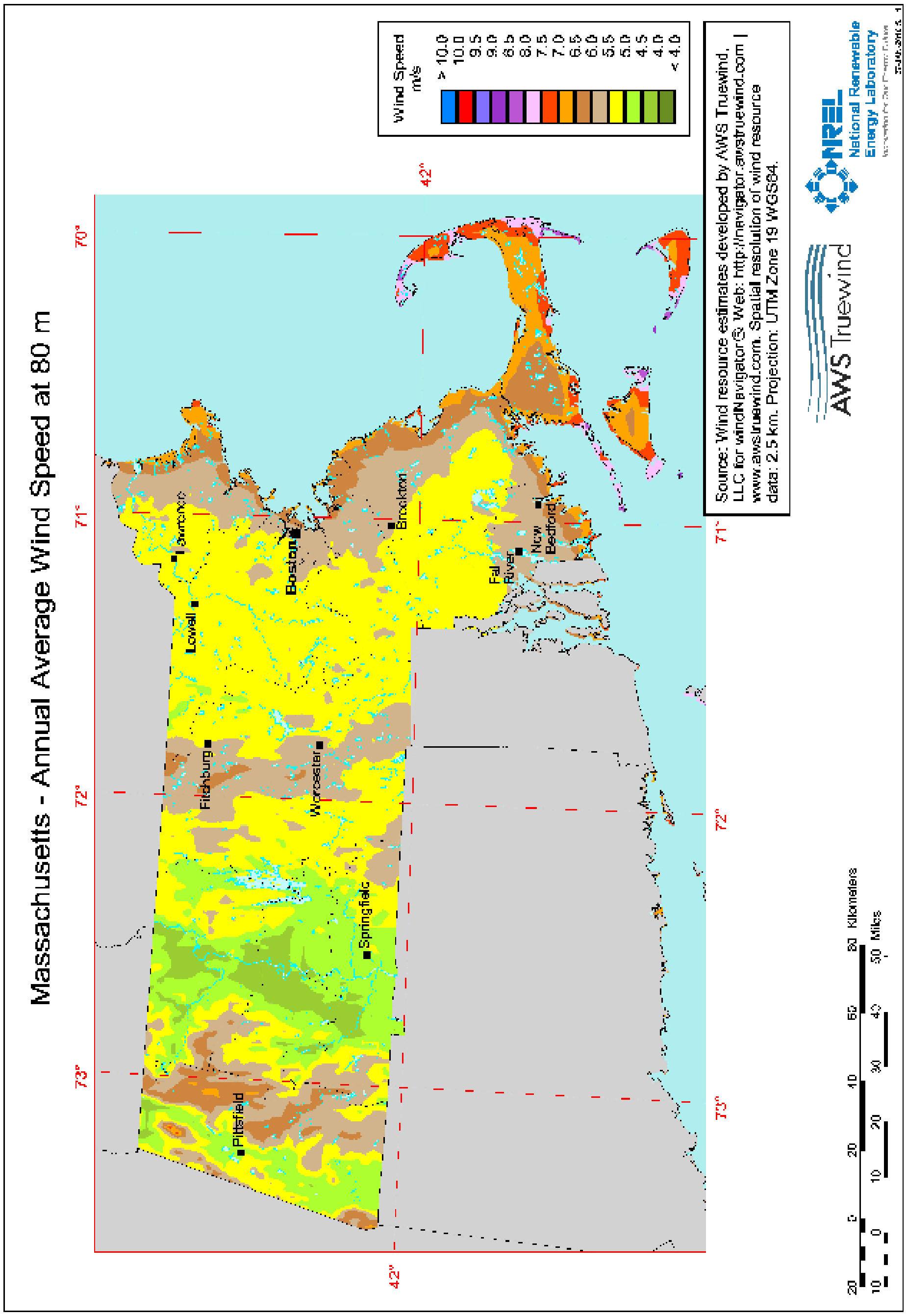


Figure 2: Massachusetts Wind Resource Map at 80 Meters Above the Ground (Energy Efficiency & Renewable Energy: Wind Powering America, 2010)

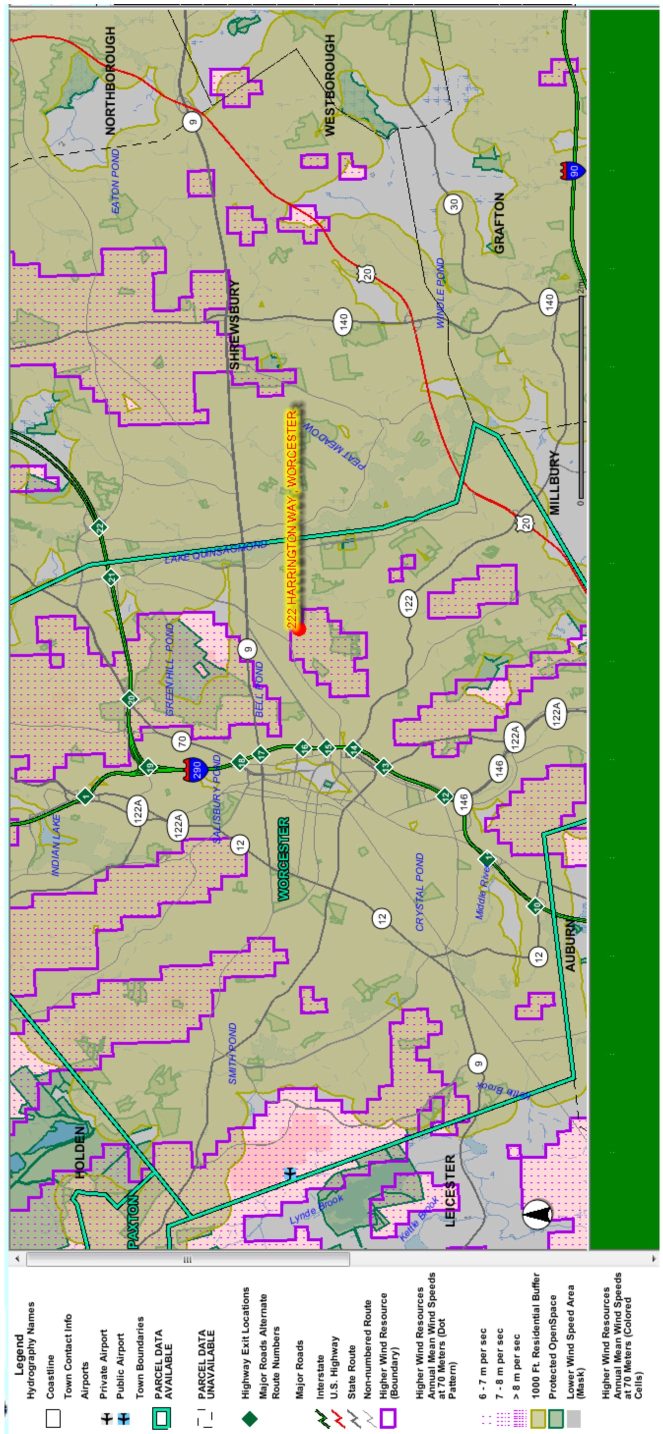


Figure 3: Massachusetts Wind Resource Map at 70 Meters Above the Ground

(Energy Efficiency & Renewable Energy: Wind Powering America, 2010)

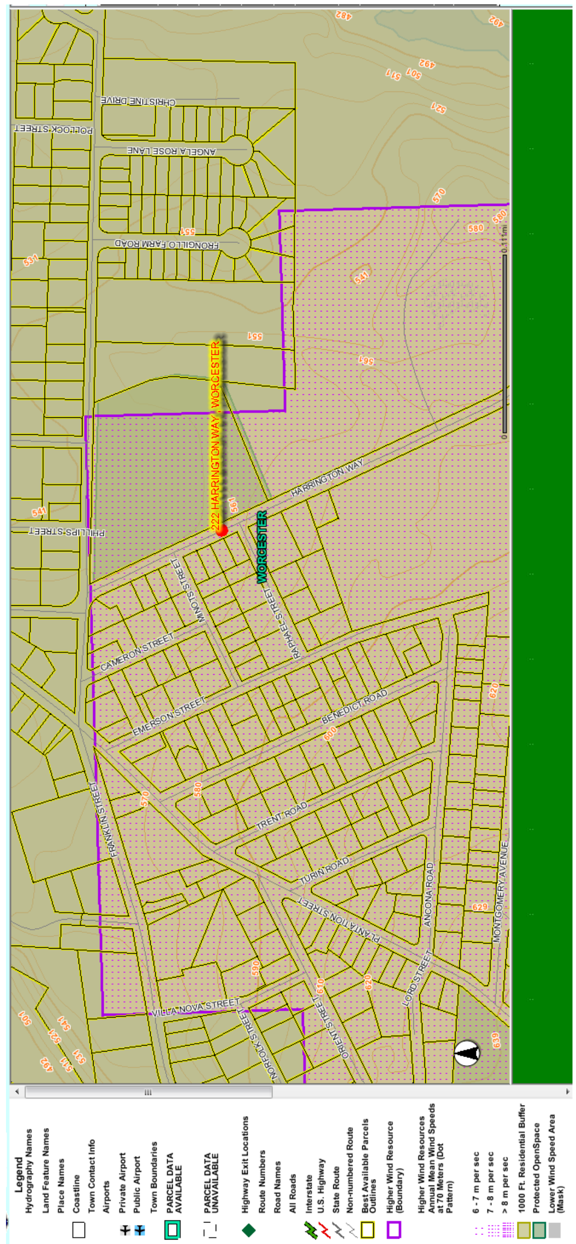


Figure 4: Massachusetts Wind Resource Map at 70 Meters Above the Ground

(Energy Efficiency & Renewable Energy: Wind Powering America, 2010)

Appendix E: Wind Technology Estimates

Advanced Energy Systems Development, LLC – Anemometer

Cost Estimate: Wind Monitoring System

Advanced Energy Systems Development, LLC
24 Hampden Street
Wellesley, MA 02482

Estimate

Date	Estimate #
11/5/2010	2010-129

Name / Address
Ecotarrium William Huard/WPI 222 Harrington Way Worcester, MA

Project

Description	Qty	Rate	Total
Power Predictor Anemometer and Data Logger	1	424.99	424.99
12 m Cable Extensions	3	33.99	101.97
Shipping	1	40.00	40.00
Installation Labor	1	1,500.00	1,500.00

Subtotal	$2,066.96
Sales Tax (0.0%)	$0.00
Total	$2,066.96

SunWind, LLC – Anemometer

November 17, 2010

300 Cranberry Highway
Orleans, MA. 02653
P.O. Box 700
Brewster, MA. 02631
888-997-8694
www.SunWindLLc.com

Anemometer Data Logger Proposal

To: William Huard
Job Location: EcoTarium
222 Harrington Way
Worcester, MA. 01604

We propose to install an APRS 6055anemometer, wind vane at the top of the existing 100 foot tower. The wind speed and direction measuring equipment shall be wired into the building where the data logger is to be located. The information can be displayed on a monitor supplied by others via USB, serial cable or web page.

We propose to install the equipment as outlined above and as shown on the quote dated November 16, 2010 for the total cost of $1,275.00 Price is valid for Thirty days from the date of this proposal.

Installation:

All work will be completed in accordance with Local, State and Federal building codes and accepted solar installation practices. All work will be performed by licensed and/or properly trained personnel. All work will be performed in a manner consistent with the safety standards as required by O.S.H.A. and the Massachusetts Department of Industrial Accidents.

Payment Schedule:

First payment of $900.00 due upon acceptance of the proposal
Final payment due upon completion.

I/We authorize SunWind, LLC to execute the formalized contract for the work as described above in this proposal, for which the undersigned agrees to pay the amount stated above and as agreed to in the terms thereof.

By: ________________________ (Client/Owner) Date: _____________

Print Name: __________________

By: _______________________ (Contractor) Date: _____________
By: Timothy S. Holmes, as President of
SunWind, L.L.C.

Quote

920 68th Avenue
Minnesota City, MN 55959
Phone: +1-507-454-2727

QUOTE NUMBER: 2010111620
DATE: November 16, 2010
QUOTED BY: Heidi Bryant
EMAIL: heidi@aprsworld.com

CUSTOMER: Tim Holmes
Sun Wind, LLC
300 Cranberry Highway
Orleans, MA 02653
508-246-6350; sales@sunwindllc.com

SHIP TO: Same

SHIPPING METHOD	TERMS	DELIVERY DATE
UPS Ground	Prepayment	ARO + 1 week

QTY	DESCRIPTION		UNIT PRICE	LINE TOTAL
1.00	APRS6055 Wind Data Logger #40R Starter Package		$ 445.00	$ 445.00
	Wind Data Logger module	North American AC adapter		
	Anemometer, #40R with boot	2 GB Secure Digital (SD) card		
	Stub mast, .3m (11")	USB SD card reader		
	APRSC1000 Anemometer cable, 30m (100')	Temperature sensor, 3m (10')		
	Mounting hardware	Printed manual		
1.00	Upgrade Anemometer Cable to 200'		$ 30.00	$ 30.00
1.00	APRS6507 Wind Vane, NRG #200P		$ 205.00	$ 205.00
1.00	APRSC1037 Wind Vane Cable, 200'		$ 65.00	$ 65.00
1.00	APRS6510 Anemometer and Wind Vane Splitter Board		$ 15.00	$ 15.00
1.00	APRS6821 Ethernet RS-232 Device Server		$ 100.00	$ 100.00
1.00	UPS Ground Shipping		$ 14.21	$ 14.21
			SUBTOTAL	$ 874.21
			SALES TAX	$
			TOTAL	$ 874.21

Prices are valid for 30 days from Quote Date.

SUNWIND LLC.
Knowledge is Unlimited Power

November 17, 2010

300 Cranberry Highway
Orleans, MA. 02653
P.O. Box 700
Brewster, MA. 02631
888-997-8694
www.SunWindLLc.com

Anemometer Data Logger Proposal

To: William Huard
Job Location: EcoTarium
222 Harrington Way
Worcester, MA. 01604

We propose to install a Davis Instruments Vantage Pro 2 Wireless weather station at the top of the existing 100 foot tower. The weather station shall provide wind speed, wind direction, barometric pressure, rain fall data and temperature. The wireless data logger shall transmit the information to a receiver located inside the building and shall be connected to the existing Ethernet connection. The information can be displayed on a monitor supplied by others via the web page software package included.

We propose to install the equipment as outlined above and as shown on the quote dated November 16, 2010 for the total cost of $1,320.00 Price is valid for Thirty days from the date of this proposal.

Installation:

All work will be completed in accordance with Local, State and Federal building codes and accepted solar installation practices. All work will be performed by licensed and/or properly trained personnel. All work will be performed in a manner consistent with the safety standards as required by O.S.H.A. and the Massachusetts Department of Industrial Accidents.

Payment Schedule:

First payment of $950.00 due upon acceptance of the proposal
Final payment due upon completion.

I/We authorize SunWind, LLC to execute the formalized contract for the work as described above in this proposal, for which the undersigned agrees to pay the amount stated above and as agreed to in the terms thereof.

By: ________________________ (Client/Owner) Date: _____________

Print Name: __________________

By: _______________________ (Contractor) Date: _____________
By: Timothy S. Holmes, as President of SunWind, L.L.C.

Davis Instruments
3465 Diablo Avenue, Hayward, CA 94545-2778

Quotation

Page 1
QUOTE No: 143
QUOTE DATE: 16 NOV 2010

CUSTOMER No: 13809

Account No 13809

SOLD TO
DAVIS INSTRUMENTS**QUOTE**
3465 DIABLO AVE.
HAYWARD, CA 94545

SHIP TO
SUNDWIND LLC
TIM
300 CRANBERRY
PH #508-247-6350
HWY ORLEANS, MA 02653

BILL TO
DAVIS INSTRUMENTS**QUOTE**
3465 DIABLO AVE.
HAYWARD, CA 94545

OUR QUOTE No	YOUR REFERENCE No	F.O.B	RESALE NUMBER	SERVICE CHARGE
143				

SHIP VIA	TERMS	DATE REQUIRED	SALES REPRESENTATIVE
UPSC	PREPAID		HOUSE USA

ITEM	QTY ORDERED ORDERED	DATE REQ'D	PRODUCT/DESCRIPTION	UNIT PRICE	DISC	NET PRICE	TAX	EXTENSION
1	1	11-16-10	06152 VANTAGE PRO2 WIRELESS	595.00		595.0000	R	595.00
2	1	11-16-10	06555 WEATHERLINK IP	295.00		295.0000	R	295.00
					Quotation Amount			890.00
						Freight		30.00
								$920.00

SunWind, LLC – Wind Turbine

Hello Bill,

I wanted to forward the introductory pricing for the wind turbine we discussed Wednesday. Here is a link to the WIPO site WIPO Wind Power GmbH<http://www.wipo-windpower.de/windcore-2.asp>

Pricing information below forwarded to me by WIPO:

Promotional pricing for the 10kw wind turbine. The dealer cost for the turbine, blades is USD $34,686.

The manufacturer is offering a 20% discount ($34,686) for the blades and turbine for the first USA order = discount of USD $5,932,

Because the reduced cost also reduces the duty this means that the price delivered to your premises will be USD $28,102 (Reduction USD 6884)

The promotional cost for the equipment is $28,102 plus inverters @ $7,000 for a total of $35,100+/-. We would also need to have a stub tower manufactured to connect the machine to the top of the existing tower approximate cost of $1,500.00. Total materials $36,600

To provide a further reassurance of our confidence in the product performance I also offer that USD $4,000 can be held as a performance bond for 6 months and is payable on the turbine performance according to expectation for the wind characteristics of the site (the exact details of this to be agreed).

Balance of project outline by SunWind, LLC

The installation would typically be $25,000+ , however we would want to cover our costs and overhead expenses. The install cost would be in the range of $7,500 to $10,000 for this unit on the existing tower. Costs include crane, underground conduit, electrical labor, turbine labor, permit fees etc... to provide a fully operational machine.

The only other cost would be engineering of the existing tower and the stub tower $1,500 to $2,500.

In closing the total installed cost would be (materials) $36,600 + (labor) $7,500 + (engineering) $1,500 = $45,600+/-

The normal installed cost for this unit is well over $100,000.

I know this is not what we had originally discussed (smaller/ vertical axis machine) although this is a tremendous opportunity to have a 10kw installed for less than half the normal cost.

I have extended this offer to two others that I know have towers which can support the installation. Please let me know if you would like me to put together a detailed written proposal for this unit.

Since the EcoTarium is a non-profit the tax credit is not applicable, unless a third party (business) were to own the machine. If a donor/business were to fund the project they could receive the 30% renewable energy tax credit as well as write-off the depreciation or simply use the donation as a write-off. Since this is a new product not on the "approved list" of equipment the state will not provide a rebate.

I will forward warranty information for the anemometer as was requested during the meeting, and will order the anemometer Monday first thing in the AM and request expedited shipping.

We will have the solar proposal prepared by midweek.

Thank You,
Tim

--
Timothy Holmes
President
SunWind LLc.
P.O. Box 700
Brewster, Ma. 02631
508-246-6350

Appendix F: Anemometer User Guide

Anemometer and Wind Study

The unit that is installed on the tower is a Davis Instrument Vantage Pro2 Wireless. The sensors included on the unit include rain collector, temperature and humidity sensors, anemometer and are housed in a weather resistant shelter. This unit is also is connected to the internet and data can be viewed on any computer with the username and password.

FAQ's

- How long to take wind data?
  - 12-15 months.
- How often does the device collect data?
  - Every hour (this can be changed based on need)
- What do I do with the data at the end of the 15 months?
  - Contact an installer or manufacturer to discuss what can be installed with your data.
- How do I know if the EcoTarium is a suitable site for a wind turbine?
  - Site is assessed to be adequate if study concludes an average wind speed above 8mph for 15 months.
- What is the website, username and password?
  - www.weatherlink.com username: EcoTarium password: kenda

Appendix G: Solar Estimates

New England Breeze

From a personal email between our team and a representative of New England Breeze:

Hello William,

Thank you for contacting New England Breeze with your questions about your project for the EcoTarium. I can provide some ballpark prices for the solar projects, but we will have to get back in touch with you next week regarding the anemometer. The following numbers can be used for your assessment, but there is not a linear relation for cost per watt. So larger systems may be slightly less cost per watt. Production will be linear.

Solar Electric (Photovoltaic)

- Estimated cost per watt installed: $7.50-$8.00 per Watt (ballast mount system on flat roof)
- Average solar panel size: 200 watts, so 5 solar panels per 1000 watts (1 kW)
- Production: every 1000 watts will produce about 1000- 1200 kWh per year
- Economic benefits: depending on the business status of the EcoTarium, they could be eligible to claim a number of incentives, including tax credits and accelerated depreciation. Visit the website: www.dsireusa.org to learn more about the economic benefits.

Solar hot water:

- 3 collector solar hot water system: $10,000
- collector size: 4'x8'
- 120 gallon tank
- This small system would provide a small portion of the hot water for the sinks in the building.

I am copying Bill Carr on this email. Bill is a WPI alum, and he is also our wind expert. I will ask Bill to follow up with you regarding anemometer costs, and perhaps he would be a good person to consult with on this project as well.

Good luck with the project!
Kristen

--
Kristen Ferguson
www.NewEnglandBreeze.com
Phone: 978-567-9463
or 508-769-2995 (cell)
Fax: 866-903-1651

Advanced Energy Systems Development, LLC
24 Hampden Street
Wellesley, MA
02482

William Huard
WPI
c/o EcoTarium
222 Harrington Way
Worcester, MA
01604

November 9, 2010

Bill,

Thank you for contacting Advanced Energy Systems Development regarding your interest in renewable energy technologies for the EcoTarium facility and thank you for showing me around the site last week. As promised I have prepared an estimate for the installation of a solar domestic hot water system and a photovoltaic system on the property along with the cost for installing a wind monitoring system.

Figure 1. Satellite Image

As we discussed, I have prepared an estimate for installing a photovoltaic system at the Apple Spice Junction restaurant. The photovoltaic system would be installed on the southwest facing wall on canter levered mounting racks to achieve maximum visibility and maximum operational effectiveness. The 1.6 kw system would be expected to generate 210 kwhrs per month on average. System cost is provided in Cost Estimate 1. Since the EcoTarium is an independent utility there are no MassCEC rebates available, however; there may be grants available to offset some of the cost. As a nonprofit EcoTarium is not eligible for a tax credit(third party ownership may be possible).

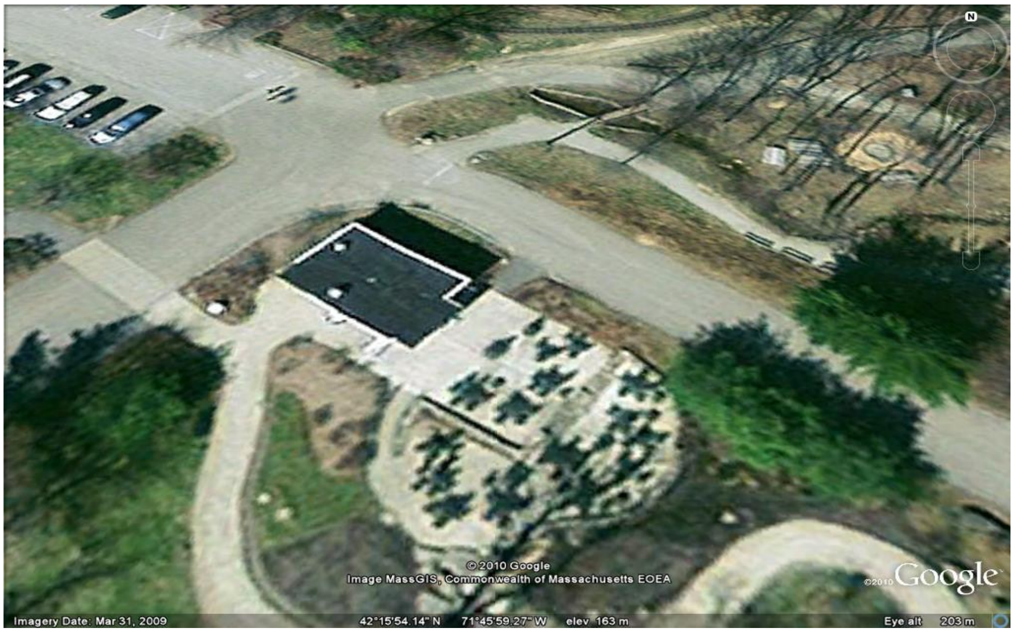


Figure 2. Apple Spice Junction Restaurant


Figure 3. Southwest Facing Wall

Cost Estimate 1
Photovoltaic System

Advanced Energy Systems Development, LLC
24 Hampden Street
Wellesley, MA 02482

Estimate

Date	Estimate #
11/5/2010	2010-127

Name / Address
Ecotarrium William Huard/WPI 222 Harrington Way Worcester, MA

Project

Description	Qty	Rate	Total
Sanyo 200 w Modules	8	775.00	6,200.00
Structral Analysis of Loads and Design for Building Permit	1	1,175.00	1,175.00
SMA Sunny Boy 3000	1	2,175.00	2,175.00
Inverter Direct Monitoring	1	260.00	260.00
Mounting Rack	8	230.93	1,847.44
Stainless Steel Anchor Screws, 3/8"	40	4.09	163.60
AC Disconnect Switch	1	637.50	637.50
DC Disconnect Switch	1	641.55	641.55
Conduit, 1"	50	2.79	139.50
Conduit, 1/2"	50	1.53	76.50
Cable	200	2.315	463.00
USE Cable w MSC Connectors	2	143.75	287.50
Combiner Box and Enclosure	1	293.98	293.98
Fuses	2	20.00	40.00
Labels	8	55.00	440.00
LA-302 AC Lightning Arrestor	1	69.78	69.78
LA-602 DC Lightning Arrestor	1	87.00	87.00
Installation Labor	8	185.00	1,480.00
Electrician	30	111.66667	3,350.00
Utility Interconnection Agreement	1	0.00	0.00
Shipping	1	550.00	550.00
Electrical Permit	1	100.00	100.00
Building Permit	1	310.00	310.00

Subtotal	$20,787.35
Sales Tax (0.0%)	$0.00
Total	$20,787.35

All of the operating parameters of the system can be displayed on a large screen monitor (not estimated). Advanced Energy Systems Development is available to assist the staff in the preparation of educational displays to accompany the photovoltaic array.


Figure 4. Canter levered Modules

A second renewable energy system to generate hot water can be installed on the roof of the Apple Spice Junction restaurant. It is much easier to incorporate the solar hot water system onto the roof than the photovoltaic system due to the presence of hvac equipment and vents. A two panel solar hot water system would generate close to 100 gallons of 120 F hot water per day during the summer months, lowering the consumption of electricity at the facility and reducing the generation of carbon gases. The existing electric hot water tank would become the backup system. Alternatively, a heat pump can be used to provide backup hot water capability (not estimated, approximately $1,000).


Figure 5. Three Schuco Slim V Collectors on a Tilt Rack, Cambridge, MA

A solar hot water system can be installed on your rear roof that will cut your consumption of electricity for hot water heating by close to 100%. This system would be installed on tilt racks located on roof curbs incorporated into the structure or self-ballasted directly on the roof membrane. During the winter months when the restaurant is not in use the thermal content of the solar storage tank can be used to heat the restaurant.

We recommend and typically install Apricus, Schuco and Heliodyne solar hot water panels. Schuco and HelioPak pump stations/heat exchangers and Super Stor, Rheem Solar Aid and Marathon solar storage tanks. The Super Stor and the Rheem Marathon tanks come with a lifetime warranty. Pictures of any of these items can be supplied. In addition to the recommended Apricus, Schuco and Heliodyne flat plate collectors we can supply Vellux, Wagner, Buderus, Viessmann and AET flat plate collectors. We can also supply Viessmann and SunMaxx evacuated tube collectors.

As requested we have also prepared an estimate for procuring and installing a wind monitoring system on the existing tower at the facility. This cost estimate is provided as Cost Estimate 3.

Please call me at the Advanced Energy Systems Development, LLC office (617 775-1720) to discuss any questions you may have concerning our estimate or if there are any additional estimates that you would like prepared.

Regards,

Charlie

Charles Nadel
Advanced Energy Systems Development, LLC
617 775-1720
www.advancedenergysystemsusa.com

Cost Estimate 2
Solar Hot Water System

Advanced Energy Systems Development, LLC
24 Hampden Street
Wellesley, MA 02482

Estimate

Date	Estimate #
11/5/2010	2010-128

Name / Address
Ecotarrium William Huard/WPI 222 Harrington Way Worcester, MA

Project

Description	Qty	Rate	Total
Schuco Slim V Collectors	2	935.89	1,871.78
Rheem Marathon 85 gl Solar Storage Tank	1	1,051.03	1,051.03
Heliodyne HelioPak 16 Pump Station	1	1,206.86	1,206.86
Glycol Loop Expansion Tank	1	134.99	134.99
Schuco 12mm Collector to Collector Fitting	1	24.31	24.31
Schuco Flat Roof Tilt Rack Kit, Self Ballasted	1	997.00	997.00
Ballast	1	225.00	225.00
Slim Duct	30	16.50	495.00
Schuco Flexible Inlet and Outlet Pipe	1	105.14	105.14
Schuco 15mm to 1/2" Adapter	1	32.45	32.45
Potable Water Expansion Tank	1	53.88	53.88
Honeywell Tempering Valve	1	107.97	107.97
Lag Screws and Washers, stainless steel	12	3.41667	41.00
Copper Pipe, 1/2", Rigid	50	1.65	82.50
Copper Pipe, 3/4", Rigid	20	2.70	54.00
Pex Tubing and Fittings	20	2.90	58.00
Fittings	15	4.16667	62.50
Hangers	5	1.25	6.25
Pipe Insulation 1" R-7.2	40	2.1615	86.46
Pipe Insulation 1/2" R 3.6	25	1.6116	40.29
TycoFur Heat Transfer Fluid, Propylene Glycol	2	73.51	147.02
Air Vent and Fitting	1	25.56	25.56
Installation Labor	24	69.75	1,674.00
Plumber, 8 hr	8	87.50	700.00
Shipping, FOB, Newington, Ct	1	170.00	170.00
Sikaflex Sealant	1	8.46	8.46
Solder, Tin/Silver(96/4) or Tin/Antimony(95/5)	1	17.72	17.72
Building Permit	1	130.00	130.00

Subtotal	
Sales Tax (0.0%)	
Total	

Page 1

Cost Estimate 2
Solar Hot Water System, pg 2

Advanced Energy Systems Development, LLC
24 Hampden Street
Wellesley, MA 02482

Estimate

Date	Estimate #
11/5/2010	2010-128

Name / Address
Ecotarrium William Huard/WPI 222 Harrington Way Worcester, MA

Project

Description	Qty	Rate	Total
Plumbing Permit	1	290.00	290.00

Subtotal	$9,899.17
Sales Tax (0.0%)	$0.00
Total	$9,899.17

Page 2

SunWind, LLC

December 3, 2010

300 Cranberry Highway
Orleans, Ma. 02653
P.O. Box 700
Brewster, Ma. 02631
888-997-8694
www.SunWindLLc.com

Solar Photovoltaic System Proposal

To: William Huard
Job Location: EcoTarium
222 Harrington Way
Worcester, MA. 01604

We propose to install a solar photovoltaic system on the flat roof of the concession stand building. The array shall face magnetic south and will be sloped between 30 and 40 degrees.

Specifications:

- Install a 5.06kw (5,060 watt) solar system consisting of (22) Schott 230 watt solar modules.
- Modules shall be installed on a "Uni-Rack" system arranged in 2 rows of 11 modules.
- Install a Solectria 5000 watt inverter adjacent to the existing electrical panel in the basement.
- Install a "DECK" data acquisition system for real time performance monitoring and automated reporting of energy production for 5 years. To extend to 10 years add $350.00
- Install metal pipe within the attic/ceiling to the electrical closet.
- Install DC and AC disconnects with placards as required per code.
- Enclose three sides of the rack with a CityScape or equal batten style roof screen enclosure.

Installed Cost:

We propose to install the solar photovoltaic system as outlined above for the total cost of $36,000.00

- Deduct CityScape roof screen $4,000.00
- SunWind, LLC shall reduce the installed cost by $3,000.00, Price is valid for Thirty days from the date of this proposal.

Incentives: *based on grid tied systems*

- MA. C.E.C. Solar II rebate of $1.00 per watt up to 5,000 watts = $5,000.00
- Ma. made component rebate of $0.10 per watt x 5,000 watts = $500.00
- U.S. Treasury Tax Credit 30% of the installed cost: 30% x $36,000.00 = $10,800.00
- Ma. Income Tax Deduction: $1,000

- Total value of incentives: $17,300.00
- Balance after incentives: $18,700.00

System Production: *based on grid tied systems*

The 5.06 kw system shall produce an average of 6,230 kwh annually. The State Solar Renewable Energy Credit "SREC" production incentive program will pay a minimum of $0.30cents/kwh for all solar energy produced by the system during a ten year contract. Based on the annual production of 6,230 kwh x $0.30cents/kwh = $1,869.00 annual savings.

Net Metering Savings of $0.17cents/kwh (current electrical rate) x 6,230kwh year = $1,059.00

Total Annual Savings/Income: $2,928.00

Balance of the installed cost after incentives $18,700.00/ $2,928.00 year = 6.38years.

The simple return on Investment is 6.5years.

The system will produce an estimated $2,900.00 for 25 years = $72,500.00 in total energy savings based on the current rate of SREC's and current electric rates.

SunWind, LLC shall make every effort to provide clients with the most accurate and up to date incentive information. SunWind, LLC shall not be held liable for any change in the amount of incentives estimated or received. We encourage all clients to discuss the incentives with their accountant to determine current and future tax liability.

Turnkey System:

- ❖ Conduct a site inspection and complete a written report.
- ❖ Complete the Ma. CEC solar II rebate application and file all paperwork in a timely manner.
- ❖ Apply for building and electrical permits.
- ❖ Submit the interconnection agreement with the utility company.
- ❖ Upon notification of the approved rebate application we shall expedite materials to the site.
- ❖ Install and commission the system.
- ❖ Request building and electrical inspections.
- ❖ Schedule utility to change existing meter to a bi-directional meter.
- ❖ Notify Ma. CEC of completion by submitting the required closeout documentation.
- ❖ Familiarize client with system monitoring and maintenance.

Installation:

All work will be completed in accordance with Local, State and Federal building codes and accepted solar installation practices. All work will be performed by licensed and/or properly trained personnel and shall meet the minimum technical requirements of the MA. C.E.C. Solar II rebate program. All work will be performed in a manner consistent with the safety standards as required by O.S.H.A. and the Massachusetts Department of Industrial Accidents.

Warranty:

SunWind, LLC shall warranty the installation of the solar system for a period of five years.

The client supplied components shall not be covered under warranty by SunWind, LLC. SunWind, LLC. shall provide service to the entire system although replacement cost of owner provided components is not covered by this warranty.

Payment Schedule:

10% due upon acceptance of the proposal
50% due upon approval of the State Solar II Renewable Energy rebate.
30% due when rack system has been installed.
10% due upon completion of inspections and interconnection with the utility.

This is a bid proposal and is intended to outline the project details, cost and incentives. Upon acceptance of this proposal a formalized contract shall be executed providing detailed terms and conditions including contract price, schedule, payment terms and your rights to cancel.

I/We authorize SunWind, LLC to execute the formalized contract for the work as described above in this proposal, for which the undersigned agrees to pay the amount stated above and as agreed to in the terms thereof.

By: ________________________ (Client/Owner) Date: _____________

Print Name: __________________

By: _______________________ (Contractor) Date: _____________
By: Timothy S. Holmes, as President of
SunWind, L.L.C.

December 6, 2010

300 Cranberry Highway
Orleans, Ma. 02653
P.O. Box 700
Brewster, Ma. 02631
888-997-8694
www.SunWindLLc.com

Solar Photovoltaic System Proposal

To: William Huard
Job Location: EcoTarium
222 Harrington Way
Worcester, MA. 01604

We propose to install a solar photovoltaic system on the flat roof of the concession stand building. The array shall face magnetic south and will be sloped between 30 and 40 degrees.

Specifications:

- Install a 2.53kw (2,530 watt) solar system consisting of (11) Schott 230 watt solar modules.
- Modules shall be installed on a "Uni-Rack" system arranged in 1 row of 11 modules.
- Install a Solectria 3000 watt inverter adjacent to the existing electrical panel in the electrical closet.
- Install a "DECK" data acquisition system for real time performance monitoring and automated reporting of energy production for 5 years. To extend to 10 years add $350.00
- Install metal pipe within the attic/ceiling to the electrical closet.
- Install DC and AC disconnects with placards as required per code.
- Enclose three sides of the rack with a CityScape or equal batten style roof screen enclosure.

Installed Cost:

We propose to install the solar photovoltaic system as outlined above for the total cost of $20,075.00

- Deduct CityScape roof screen $2,500.00
- SunWind, LLC shall reduce the installed cost by $1,500.00, Price is valid for Thirty days from the date of this proposal.

Incentives: *based on grid tied systems*

- MA. C.E.C. Solar II rebate of $1.00 per watt up to 5,000 watts = $2,530.00
- Ma. made component rebate of $0.10 per watt x 5,000 watts = $500.00
- U.S. Treasury Tax Credit 30% of the installed cost: 30% x $20,075.00 = $6,022.00
- Ma. Income Tax Deduction: $1,000
- Total value of incentives: $10,052.00
- Balance after incentives: $10,022.00

System Production: *based on grid tied systems*

The 2.53kw system shall produce an average of 3,120kwh annually. The State Solar Renewable Energy Credit "SREC" production incentive program will pay a minimum of $0.30cents/kwh for all solar energy produced by the system during a ten year contract.

Based on the annual production of 3,120kwh x $0.30cents/kwh = $936.00 annual savings.

Net Metering Savings of $0.17cents/kwh (current electrical rate) x 3,120kwh year = $530.00

Total Annual Savings/Income: $1,466.00

Balance of the installed cost after incentives $10,022.00/ $1,466.00 year = 6.8years.

The simple return on Investment is 7 years.

The system will produce an estimated $1,466.00 for 25 years = $36,650.00 in total energy savings based on the current rate of SREC's and current electric rates.

SunWind, LLC shall make every effort to provide clients with the most accurate and up to date incentive information. SunWind, LLC shall not be held liable for any change in the amount of incentives estimated or received. We encourage all clients to discuss the incentives with their accountant to determine current and future tax liability.

Turnkey System:

- Conduct a site inspection and complete a written report.
- Complete the Ma. CEC solar II rebate application and file all paperwork in a timely manner.
- Apply for building and electrical permits.
- Submit the interconnection agreement with the utility company.
- Upon notification of the approved rebate application we shall expedite materials to the site.
- Install and commission the system.
- Request building and electrical inspections.
- Schedule utility to change existing meter to a bi-directional meter.
- Notify Ma. CEC of completion by submitting the required closeout documentation.
- Familiarize client with system monitoring and maintenance.

Installation:

All work will be completed in accordance with Local, State and Federal building codes and accepted solar installation practices. All work will be performed by licensed and/or properly trained personnel and shall meet the minimum technical requirements of the MA. C.E.C. Solar II rebate program. All work will be performed in a manner consistent with the safety standards as required by O.S.H.A. and the Massachusetts Department of Industrial Accidents.

Warranty:

SunWind, LLC shall warranty the installation of the solar system for a period of five years.

SunWind, LLC. shall service the system at 18 month intervals during the five year warranty period to ensure optimal energy production.

Solar modules carry a manufacturer production warranty of 25 years.

The Inverter manufacturer standard warranty is 10 years. Extended warranty available upon request.

Payment Schedule:

10% due upon acceptance of the proposal
50% due upon approval of the State Solar II Renewable Energy rebate.
30% due when rack system has been installed.
10% due upon completion of inspections and interconnection with the utility.

This is a bid proposal and is intended to outline the project details, cost and incentives. Upon acceptance of this proposal a formalized contract shall be executed providing detailed terms and conditions including contract price, schedule, payment terms and your rights to cancel.

I/We authorize SunWind, LLC to execute the formalized contract for the work as described above in this proposal, for which the undersigned agrees to pay the amount stated above and as agreed to in the terms thereof.

By: ________________________ (Client/Owner) Date: _____________

Print Name: __________________

By: _______________________ (Contractor) Date: _____________
By: Timothy S. Holmes, as President of
SunWind, L.L.C.

Appendix H: Data from the Museum of Science

Museum of Science

Exhibit Development Process: *how does an exhibit come to life?*

Idea Development

The exhibit topic (in this case, Renewable Energy is already decided)

Concept Development

- Brainstorm learning goals
- Literature searches relevant to the overall topic
- Map the exhibit goals to curriculum frameworks
- Front-end research about what visitors already know and want to know about the topic
- Brainstorm interactive ideas, activities that visitors would do, and other exhibit components
- Begin to design footprint of exhibit and visualize the look and feel
- Decide which ideas will go into prototyping phase (refine list)

Prototyping Phase

(Using the refined list of component ideas)

- Determine what the visitor will do at each exhibit component
- Define learning goals for each component
- Create very rough prototypes of each component to be tested, including labels
- Prototype with visitors
- Continue iterative cycle of improving, testing, and further developing each component – including labels – until ready to build and try out without supervision
- Create final design and graphic approach for exhibit
- Ensure that all components meet Universal Design criteria

Build, Install & Test Phase

- Build sturdy components that will ultimately evolve into final component
- Test for usability and durability on Exhibit Halls
- Build non-interactive components (if any)
- Install exhibition

Evaluate & Remediate Phase

- Evaluate for usability and learning goals with visitors
- Evaluate with Exhibit Maintenance for durability
- Make any remedial changes necessary
- Finalize Exhibit Maintenance Manual
- Document for Archives

Word Association

Renewable Energy project – Word free association

Melting	Regulations
Ice cap	Sacrifice
Sea level	Systems/interconnected
Monitoring	Subsidies
Jobs	Mind-set
Environment	Habits
Weather	Plan
Climate	Lifestyle
Future	Behavioral change
Infrastructure	Overwhelm
Wind	Landfill
Nuclear	Oil
Potential	Conservation
CO2	China
Footprint	Hippie
Consumption	Trade-offs
Cycle	Stewardship
Wildlife	Flow
Consumer	Confusion
Context	Complicated
Local	Silence/sound
Family – home	Distributed
Intergenerational	Visible/invisible
Depleted	Deprivation
Educate	Value
Shortage	Diode
Backyard (NIMBY)	Ancient
Crisis	Abundant
Politics	Partisan
Scarce	Responsibility
High-tech / low-tech	Transmission
Intermittent	Profit
Sacrifice	Distribution
Decision	Region
DC/AC	Disposable
Innovation	Community
Limited	Conservation
Green	Nature
Waste	Grid
Solar	Replace
Power	Storage
Sustain	Clean
Cost	Electricity
Expensive	Yellow
Innovation	Sun
Time-scale	Essential
Durable	Al Gore

Updated 21 April 2010 Jane Jolkovski

Museum of Science Exhibit Ideas

Museum of Science
Jane Jolkovski
617.589.4414

Ideas for Renewable Energy Exhibit – our initial list of ideas

Theater of Electricity Energy Diagram

We are implementing this

Summary Description:

Dynamic graphic that conveys the equivalence between the energy from the PV panels and the energy used by the theater

Main Messages:

Photovoltaic panels on the roof generate electricity from sunlight.
The energy generated by the panels equals the amount of energy used by the Museum's Theater of Electricity.

Description of Visitor Experience:

A dynamic graphic uses sequenced light or sequenced panels to depict: (a) sunlight hitting PV panels of roof; (b) photovoltaic panels producing electricity as a result; (c) that electricity feeding a communal grid and being captured by an energy counter or meter; (d) that same amount of energy flowing to the Theater of Electricity.

Furthermore, those balanced energy units are linked to at least one real-world, everyday reference. Visual form might include a balance/scale with a direct reference line to the everyday unit or reference. (Depending on space and possible distraction from main communication goal, there could be several equivalent everyday references.)

Design includes clear, step-wise process graphic that follows the energy flow from sun to panel to grid to theater, assigning a simple, clear name to each step. Envisioning a dynamic, self-paced graphic, but could be achieved with a static graphic if necessary. Supporting activity options include a cartoon-style drawing template that lets visitors re-cap the process for themselves and/or a set of "story cards" that let visitors recapitulate and reconstruct the sequence.

SCREAM-meter

We decided not to do this one. We loved the fun of it and felt it would be very engaging; however, we felt that the units of measure were too awkward to be meaningful enough to the visitors. Also, would have been very costly and a challenge to make it universally accessible (e.g., for wheelchairs) and we liked our other interactive ideas better.

Summary Description:

Visitors create their own sound energy and gain an intuitive sense of the energy needed to power an everyday object like a light bulb.

Main Messages:

I can produce energy!
Sound is energy.
I can see and feel (and hear) how much energy it takes to power a light bulb.

Description of Visitor Experience:

Visitors scream into a "scream-meter" which gives feedback about how much sound energy they've produced and what multiple of that energy would be needed to power a 100 Watt bulb for a given time – i.e. 1 second.

Suggested "scream time" = 5 seconds, with countdown and visual cue provided. Activity mechanism uses an actual dB meter to link sound intensity to power. That power over the 5- second interval will produce an energy unit. With a "playback" that responds to the input, visitors will see and hear a simulation of scale that maps how many multiples of that energy input it would take to power a 100W light bulb for one second.

Playback includes layered sound that replicates the visitors own scream along with a clear numerical multiple.

Energy Jumper

We decided not to do this one. Again, our main concern was how could we make the units of measure meaningful, even though this interactive would have been fun!

Summary Description:

Visitors exert physical energy that maps to 1 BTU – energy that's actually used to express the meaning of a BTU – and then visitors see this energy scaled up to match average energy use for a home in MA.

Main Messages:

I can make energy by moving by body or making something happen.
I can experience how much energy equals one BTU, and I can tell how many of those units are needed to power a house in MA.
Compared to the energy I can make on my own, we need a LOT of energy. On average, one MA home needs 2 million jumper units!

Description of Visitor Experience:

Visitors step on a scale and then, based on weight, are cued to jump at a rate of once per second for a period of time to produce the equivalent of 1 BTU.
(Example: a 100-lb person would need to jump for 20 seconds.)

Visitors see the direct effect of the energy they've produced by reading a thermometer that's gauging the temperature increase of 1 lb of water. The visitor's energy production actually heats the water by 1 degree F.

A high-impact display converts that experiential energy unit into the scale of the avg home in MA: a scaling factor of 2 million!

An accompanying blow-up of a sample energy bill supports the message.

Where Does Our Energy Come From? / Where Does Our Energy Go? or perhaps Sources & Uses: Local and Global

We are implementing this. Challenge is how to present so much relevant information in a way that doesn't overwhelm/bore the visitor. Also, info must remain relevant and current through the life of the exhibit (estimate 10 years).

Summary Description:

Large-scale, visually compelling, easy-to-understand graphic that maps and compares energy sources for the world, the US, and MA.

Main Messages:

We get energy from different sources, including fossil fuels, nuclear power, and renewable sources.
The breakdown of sources is different for the world, the US, and MA.

We use energy for different purposes.
I can "see" information.

Description of Visitor Experience:

Visitors see and study graphic depictions of world, US, and MA sources and uses of energy. Question sparks and prompts help visitors engage with and interpret the information. Key activities are: understanding and visualizing the data; interpreting and comparing patterns; gaining familiarity with naming and grouping sources and uses. Visitors also use the information provided and questions posed as guides for shared conversation.

Renewable Sources

Aspects of this component are being incorporated into Sources & Uses and into the chart at accompanies Power Boston.

Summary Description

Interesting, attractive iconographic "inventory" of renewable sources with key information related to function, feasibility, challenges, current status, etc.

Main Messages:

There are lots of sources of renewable energy – the sun, wind, the oceans, flowing water.
Each source has its benefits and challenges.
Some sources aren't a good fit for some environments.
I want to find out more about renewable energy.

Description of Visitor Experience:

Visitors see and engage with a clear, attractive, easy-to-understand 2D or 3D graphic that depicts each renewable energy source with an icon (creating a family of icons) and that provides key information for each source. Information includes: basic summary of function and identification of core source, pervasiveness of use (in MA), benefits, energy efficiency, challenges, visual example, and related objects.

Visitors use a card deck - Sintra blocks, for example - to "collect" and compare sources - like baseball cards or national flag cards. (This theme could extend to merchandising a renewable energy card game or energy bingo for the Museum's gift shop.)

Through this panel and related interactives, visitors see and understand what "renewable" means – though this could well be achieved with other words.

Solar Lab (w/ additional names for each component)

This initial idea evolved into two interactive components: Solar House & Solar Collector.

Summary Description:

Several linked activities give visitors the chance to explore, see, understand, and play with concepts related to solar energy: passive, direct (solar thermal and concentrating solar), and photovoltaic panels.

Main Messages:

The Sun is an energy source.
We have technologies that help us capture and use the Sun's energy.
We can make design choices for our buildings that use the Sun's heat, light, and shadow as design elements.
We can use the Sun's heat directly.
We can use mirrors to focus and direct the Sun's heat. The focused heat can be used to boil water to make steam, which can be used to generate electricity. Solar collectors "add up" and concentrate the Sun's heat.

When sunlight hits a photovoltaic panel, its energy gets converted into electricity. Electricity is a flow of electrons. Photovoltaic panels are made up of semiconductor materials that respond to light energy by releasing electrons.

Description of Visitor Experience:

In an area with several inter-related activities supported by a shared environment and a solar "source", visitors explore an array of hands-on activities:

Using a mounted slot-system and an array of loose elements, visitors create their own building designs to test light, shadow, and heat effects. Sensors provide real-time feedback on key metrics that would correspond to heat/energy efficiency. Added activity layer could include "design challenge" cards providing visitors with desired criteria or functional use requirements.

A mounted camera with real-time feedback can help visitors "see" the light/shadow profile of their designs from a perspective inside the structures they've created. A shared surface can promote peer-to-peer communication and decision-making.

Visitors shift and direct a set of mirrors to focus light onto a collecting tower. A feedback metric tracks and displays capacity based on the orientation of the mirrors. At threshold capacity, the system depicts throughput process of heating water, creating and capturing steam, and producing electricity. To enhance the concept of using reflection to concentrate the Sun's energy, a separate display model uses physical vector lines to represent Snell's Law.

Visitors pivot a mounted PV panel to explore the effects of alignment and then make a choice about where to direct the electric power. In a related Be-a-Solar-Panel activity, visitors use their own bodies to orient to a source. Based on the surface area presented and the angle of orientation, a read-out displays how much energy each visitor would generate.

Also in the Solar Lab: Visitors will see a replica of and/or additional materials related to the informational panel inside the Theater of Electricity, possibly including a scale model cut-away, images of PV panels on the Museum's rooftop, and cumulative meter readings showing the balance between energy input from panels and energy use of theater. This is where we can show one meter running "backward" and another running "forward".

Energy Landscape

We decided not to do this one; some aspects of it are incorporated into Power Boston.

Summary Description:

Visitors "dial up" relative percentages of energy to power a neighborhood / town and see a visual depiction of the resultant landscape.

Main Messages:

We can make choices about which energy sources to use.
Those choices will impact what our neighborhoods and towns look like.

Description of Visitor Experience:

Visitors use turn-knobs or slider bars to assign percentages to energy sources. (Inter-connected choices lead to 100 %.) Based on the sources chosen and the respective percentages, an "energy landscape" image is produced. Visitors can re-select again and again, crafting new landscapes.

Power Boston

This one evolved into the interactive that you saw (the prototype). We went back-and-forth about whether to do this as a computer interactive or a physical one – eventually landing on the physical. Felt this would be more engaging, visceral, and accessible to more visitors.

Summary Description:

Visitors use smart-block inputs to design a power system for a city – i.e. Boston.

Main Messages:

We can work together to make choices about our city.
It takes different energy sources to supply the power we need.
Every set of choices has benefits and challenges.
MA has a lot of energy options.

Description of Visitor Experience:

Visitors work together or on their own around a topo table depicting the city of Boston and its surrounding areas. Using coded smart-blocks that visually and electronically link to energy sources, visitors plug in and test choices with the goal of "powering up" the city. The smartblocks and embedded smart grid allow visitors to use the natural landscape as well as the built environment to solve for and provide the city's power.

The vertical buildings could be used as synced meters, marking power progress. At max power, the city "activates" and draws down power, thus starting the cycle again.

Wonder Bar

We are implementing this component.

Summary Description:

A bank of compellingly-displayed objects creates a clear link between an object, a MA-based energy technology, a person, and a story. Visitors can see and hear from each person through short video clips and can leave behind questions.

Main Messages:

There's a lot of research about renewable energy going on in MA.
These scientists seem like they really love what they are doing!
Cool, I never knew you could get energy from ….
I wonder where else energy can come from. I want to know more.
Research can require technology, and research can produce technology.
I can connect with real people doing real science where I live.

Description of Visitor Experience:

Visitors see authentic artifacts related to innovative MA-based energy technologies. Objects are artfully displayed in vitrines, perhaps including edge lighting that calls attention to each artifact.
(This element could be a "featured visual" for entire exhibit area.)
Associated with each artifact is a descriptive panel (perhaps with a breaking news-style format) and an interactive video monitor featuring the scientist/engineer/innovator/entrepreneur who is the force behind the energy innovation.

Each video screen has three or four inputs that visitors can choose from labeled with clear titles that convey what the clip will address. Each choice triggers a short excerpt that expands on the chosen topic. All clips convey the respective person's passion for his/her work and the possibilities they are exploring.

Visitors have the chance to write down questions they want to ask based on the technologies they've seen and the people they've "met" through the videos.

Energy Gallery

We are not implementing this, per se; however, we are planning some kind of renewable energy art installation in our main lobby (I forgot to mention this part to you!). The goal is to attract attention, have a "wow" factor, and then guide visitors to the exhibit.

Summary Description:

Display of energy-inspired art.

Main Messages:

People are thinking about energy in lots of different ways.
Energy-related art can be beautiful and interesting.
These ideas make me think about…

Description of Visitor Experience:

Visitors explore a graphic display (or sequenced photo frame-style display) depicting energy related art pieces. A drawing table encourages visitors to replicate, combine, or adapt the images into their own ideas and designs.

Desired Impacts:

Visitors are surprised, inspired, delighted, curious.
Visitors see models of hybrid problem-solving that combine aesthetic and analytical thinking.
Visitors see energy as a tool for design and art as well as for science.
Visitors appreciate the breadth of content offered by the Museum.
Visitors identify themselves as creative thinkers and problem-solvers.

Control Room

We decided not to do this. Too complex and would rely on visitor interaction – not always feasible.

Summary Description:

Sound and video mixing "lab" where visitors can hear, assess, mix, and present their own collages of energy information.

Main Messages:

People are talking about energy.
There's a lot of information to absorb.
I can figure out where to get more information when I need it.
I want to understand things for myself.

Description of Visitor Experience:

Visitors use a wide array of source materials to mix audio and video clips about energy. Prompts support guided choice-making, though visitors can also create "free-form" montages. A time-out limits length of clips. Visitors can present and share their clips.

Energy Plaza

We had hopes of being able to place some kind of artwork or attractor in the area outside the front of the Museum (what we call the Plaza), but cost and logistics were prohibitive within the scope of this project.

Summary Description:

Interactive elements engage visitors in playful activities based on sunlight, shadow thermal energy, and other natural elements.

Main Messages:

Energy can create movement.
I can make things happen with my own energy.
I can play with light and shadow.
The Sun's energy, the wind, and other inputs from the environment can create unpredictable and interesting effects.
It's fun to "play with" energy!
I want to see what's inside.

Description of Visitor Experience:

Interactive elements on the plaza could include:

Solar Fountain: Visitors control a PV panel to produce energy that powers a series of fountains. Visitors can make choices about the panel's orientation (total energy) and also about how to distribute the energy to create different fountain patterns.

Light / Shadow sculpture: Visitors shift and move large-scale-but-portable sculptural pieces to create unique light/shadow effects.

Light Arbor: A covered walk-way is lined with a series of different light-sensitive materials that create color and thermal effects as visitors walk underneath.

Kinetic wind sculpture that creates and reveals inter-dependence between wind effects and light effects.

Be-a-Solar-Panel interactive that replicates or links to activity inside Museum

Solar collector interactive that foreshadows the activity inside the Museum; interactive could create effect visible from a distance.

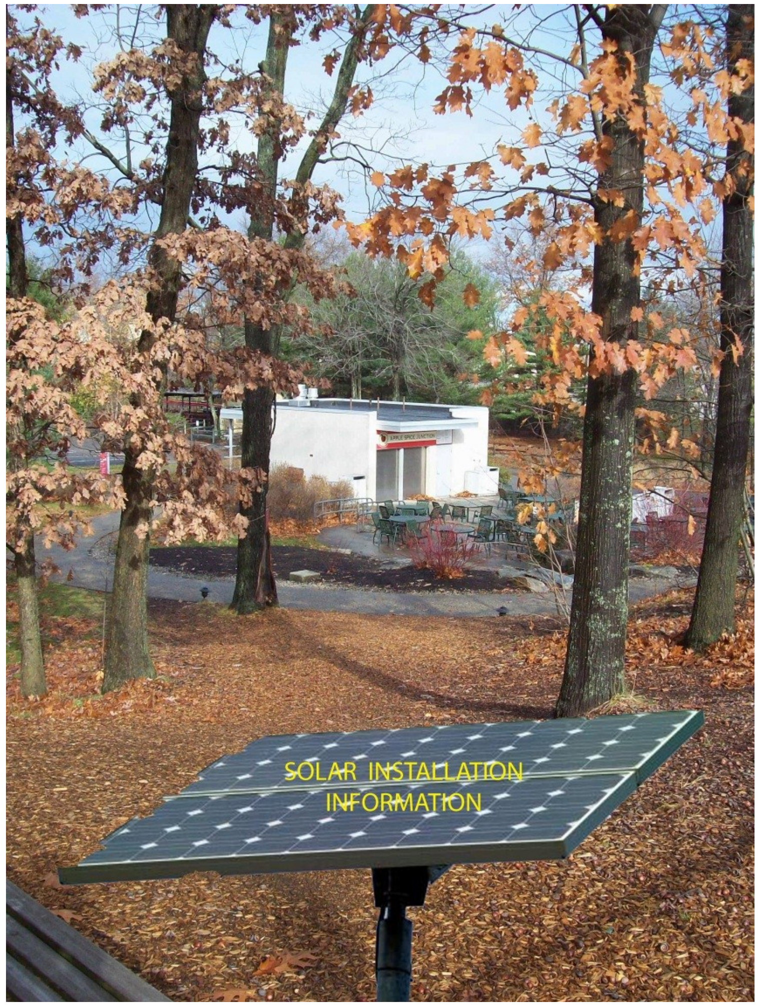
Use solar energy to power something interesting a fun… One project currently under development will include a solar-powered coffee stand. Some plazas have solar-power compactors. What would be significant and appropriate for the Museum?

Appendix I: Exhibit Concept Data

PV Solar Array Explanation Display

Summary Description:

Engaging graphical display that clearly demonstrates the similarity between the solar panels on the roof of the Apple Spice Junction and a residential-sized system.



Main Messages:

The photovoltaic system installed on the Apple Spice Junction is the same size that I could install on my home

I can save money on energy by installing a system like the EcoTarium

This is what solar panels actually look like and how they are attached to a roof

Description of Visitor Experience:

Just outside the back entrance to the EcoTarium, in view of the Apple Spice Junction, guests will come upon a display that appears to be a solar panel mounted to the ground instead of a roof. Upon further inspection, guests will discover that it is an informational display about the system they can see on the distant Apple Spice Junction roof. The display will be scaled to the size of a real solar panel and will contain the relevant system information in a way that guests can understand.

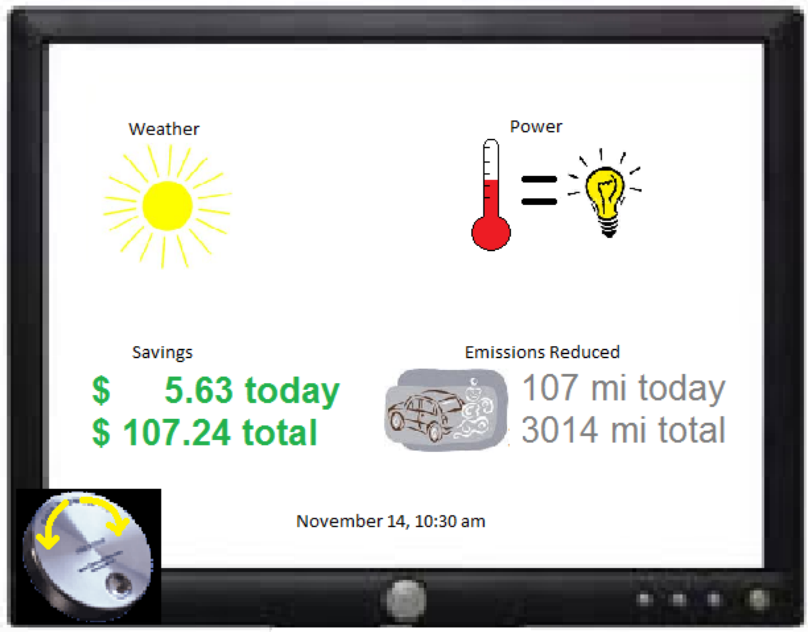
The display could contain such information as:

- System size
- System type
- Power produced (related to home power use)
- Percent of energy bill that can be saved
- Components installed such as the inverter, rack, and panel

This information can then be related to consumers, as the system installed on the Apple Spice Junction will be a residential-type application.

Time Lapse Exhibit

Summary Description: A set of spin wheels that allow the user to explore real-world data on solar panel installations and solar panel power output.



Main Messages:
How a system is physically attached to a roof.

This is what a real solar panel installation looks like.

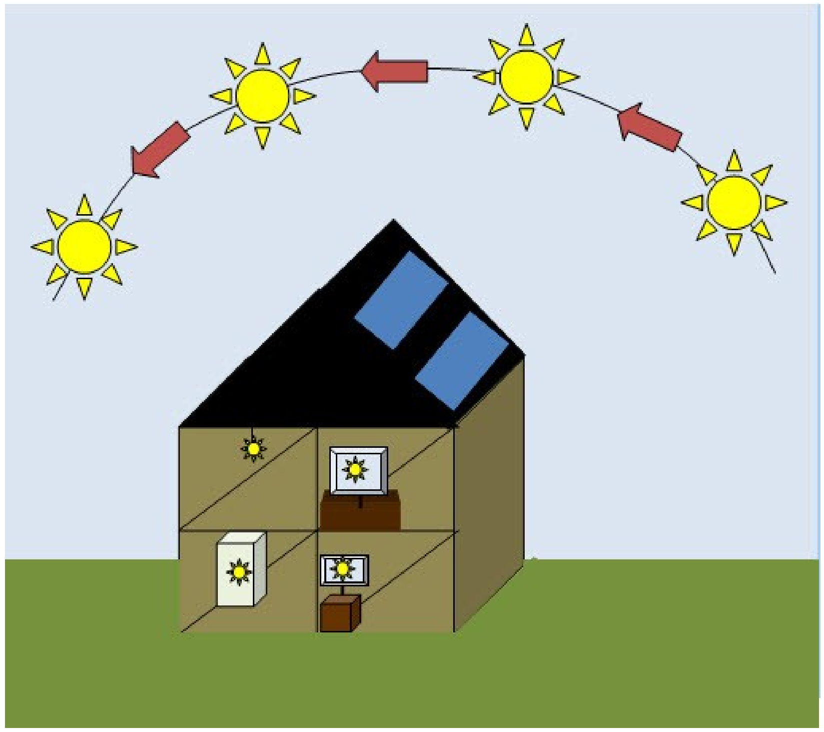
Solar panel power output depends on time of day and weather conditions.

Over time, solar panels can save you money.

Using solar panels also reduces pollution.

Description of Visitor Experience:
Exhibit contains two spin dial displays, one for an installation video and one for solar panel power output.
The first spin dial lets the user view the installation of the EcoTarium's own solar panels at their own pace. They can slowly watch each step being taken and each piece being used, or they can skip through and watch the roof go from empty to covered in solar panels. At the end will be a close-up on the roof to show the final setup. Accompanying this video may be text on the side informing the visitor of what each component seen in the video is used for or the general process for accomplishing a solar panel installation.
The second spin dial lets the user view the current and past power output of the solar panels. Spinning the dial seeks to different days and times. For each recording, this portion of the exhibit displays the time of day, general weather information, and power output. In addition, the power output data is "interpreted" for more meaningful information. This information displayed will include the amount of money saved over a period of time, perhaps by day or by year. May also use a rate of savings, such as current dollars saved per hour or day, or the estimated return on investment timeframe. Also include the environmental impact, using raw data along the lines of "pounds of carbon dioxide eliminated," then equate that in a more understandable term, such as equivalent automobile emissions.

Solar Playhouse



Summary Description:
An exhibit that lets the guest interactively learns how the position of the sun and sun intensity influence the energy production of solar panels. The exhibit also allows guests to learn the different energy outputs of different size household solar systems in a way that accommodates all ages.

Main Messages:
The sun is a source of energy

Solar panels use the suns energy to produce power

Different time of the day the sun is at different angles

Different angles produce different amount of energy

The amount of shade will affect the power output

The direction the solar panels should face

How much power can the average setup power at different times of the day

Description of Visitor Experience:
A dollhouse type display will be used with a sliding light, acting as the sun, will be above the house that slides over from one side to the other. The light will have a handle so the guest can interactively move the light from sun rise to sun set over the house. There will also be a switch on the light that dims the light to act as a cloudy day or shade on the solar panels. The house will contain rooms with certain appliance in each room such as a refrigerator, a TV, a light and when there is a sufficient amount of power generated by the solar system the appliance lights up. There will also be a output screen that shows how much each energy each appliance needs and how much energy would be generated at that time. On the same screen will be a dollar bill that grows light is moved from morning to evening showing how much money is saved during the day. There will be a question to when the most power is generated. This question is posed so that the guest has to move parts and interact to find where the optimal locations of the panels are and what time would produce the most power.

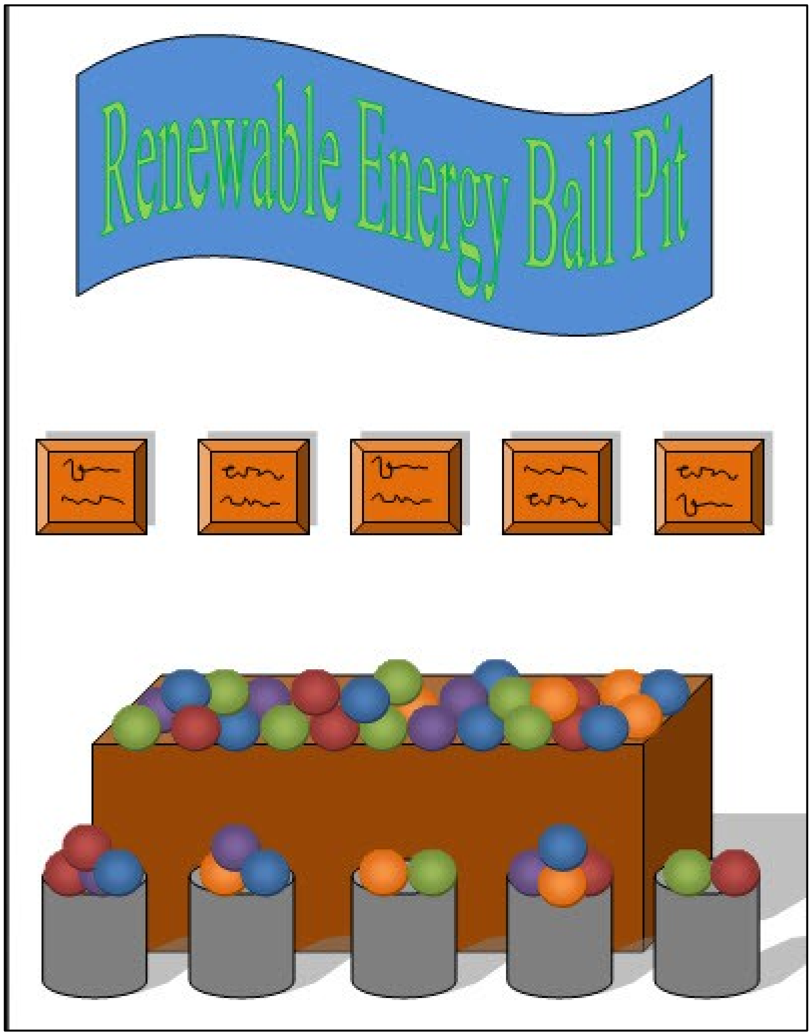
Fossil Fuel vs. Renewable Energy Trail

Summary Description:

This is complimentary to the Energy Trail Exhibit concept.
It could be a "fork" in the road type path, where visitors would choose a path, i.e., one is the Fossil Fuel Path and the other is the Renewable Energy Path.

OR

The Energy Trail Exhibit could start off with the Fossil Fuel Trail that leads into the (Renewable) Energy Trail Exhibits.



Main Messages:

There are many sources of energy (Non-renewable and Renewable)

Non-renewable energy sources produce waste/byproducts that are harmful to our environment (destructive)

There is a need to support renewable energy as our choices in energy use will have an impact on our environment

I want to learn more about these renewable energy sources

Description of Visitor Experience:

Visitors will travel down: a) choose their path; b) start down the fossil fuel path in which both will depict the information associated to fossil fuels and renewable energy sources (possible indoor/outdoor or just outdoor only):

a) Choosing their path:

This will allow visitors to make their own decision and allow them to view the future consequences due to this decision. Will they choose a fossil fuel future and see its destructive forces? Or, Will they choose a renewable energy future and learn about its benefits to the environment and future generations? If they choose the fossil fuel future, it will eventually lead to a world that cannot be sustained and it will then direct them to the (renewable) Energy Trail Exhibits to learn about what the future could have been if they had chosen that path first.

b) Starting down the fossil fuel path:

This would be the beginning of the (Renewable) Energy Trail Exhibits. This would allow visitors to learn about our present day energy uses and the consequences of fossil fuels. It would then give the visitor the impression that there is a need for renewable energy sources and interest them in learning more. Then, the renewable energy exhibits and information would be presented along the rest of the trail. (This is the same idea as "Choosing their path", but it would inform all visitors that there is a need for change, not just the ones who chose the fossil fuel path first)

There are multiple options for displaying such information:

1. The path could be lined on both sides or just one with plywood. The plywood boards would display painted or drawn images of fossil fuels and a forest environment (or any environment for that matter). There would be text based information on how these fossil fuels destroy the environment. When visitors first enter the exhibit, the environment would be for the most part undamaged and unharmed. However, as visitors travels down the path the environment on the display would decline and portray a damaged and harmed look. It would eventually lead them with ideas that renewable energy can be used to reduce the declination of the environment and help restore it. The environment would then return to a healthy display as they begin their journey on the (Renewable) Energy Exhibit Trail, where they would go to learn about how these energy sources are eco-friendly.

2. The beginnings of the (Renewable) Energy Trail Exhibit and Fossil Fuel Trail could be incorporated on the inside of the building pending the EcoTarium's vision for the remodeling of the Museum. This would portray the same concepts as if it were outside, but gives the chance for the EcoTarium to take advantage of a more interactive approach of teaching these concepts, as the displays would be protected inside.

2.1 Possible ideas for interactive exhibits inside

Board Game: The board game would be located inside the EcoTarium and would contain portable pieces. It would simulate walking the path outside, but be on a smaller scale. Children could walk this path and learn about both fossil fuels and renewable energy through flip up tiles with pictures/text. There could also be blow up representations of these energies, i.e., wind turbine, solar panel, power plant.

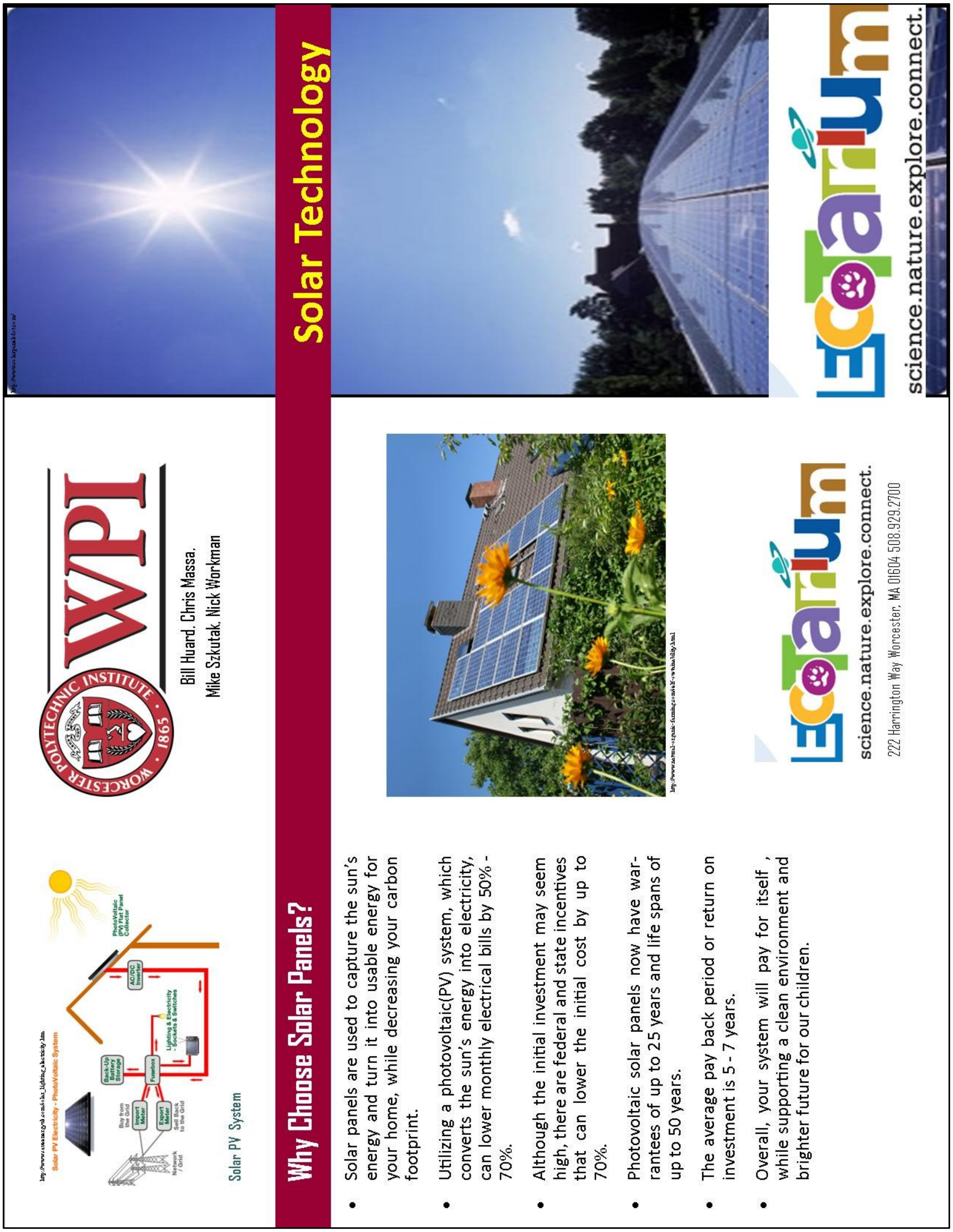
Renewable Energy Ball Pit: The ball pit will contain balls that are colors that pertain to certain energies. (Solar = yellow, Wind = White, Hydro = Blue, Coal = Black, Nuclear = Green, etc. . . .) There would then be a panel/plaque and basket that would ask the child to go and collect up to 5 balls of any color. Then when the child brings the balls back and places them in the basket, the parent could read to the child what the corresponding colors meant due to the environmental impact of the choices. (Examples: You need 3 blue and 2 white balls to save Racket in his natural environment, and the child would go get them. OR There could be multiple baskets that have certain color combinations the child would have to retrieve. Then once those combinations are complete a flip up panel with text or an animation could show them what the impact was)

Computer Game: This would be the same as the board game, but a video version that could incorporate higher quality graphics in which the user would make choices with buttons provided at the station. There could be multiple buttons for multiple users. Each choice made would then have a consequence that would be displayed.

3. There could also be informational displays at each animal exhibit on the wildlife path and how non-renewable or fossil fuel energy sources are affecting the specific animals habitat. For example, fossil fuels are causing global warming, which cause the ice caps to melt, which in turn, if attributing to endangering the polar bear species, Kenda!

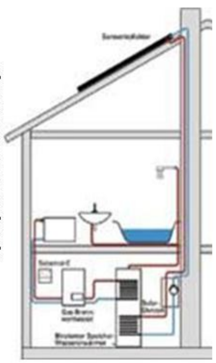
Appendix J: Mock-Up of Informational Guides

Solar Pamphlet



Solar Hot Water

- Solar hot water panels use sunlight to heat water for basic household needs such as laundry
- Solar hot water collector systems can save 60-70% on you annual water heating bills



Solar Hot Water System

  - Annual savings between $100 and $400 per year.
  - Can provide 100% of households needs in summer, 30% in the winter
  - Typically require between 50 and 100 square feet roof space
  - Needs a site that is unshaded between 9am an 3pm
- Not as partial to shading as PV system but consider suns path in all seasons as well as shading from trees, chimneys or other buildings
- Small hot water system (50-60 gallon storage) is sufficient for 1-3 people.
- 4+ people require 80-120 gallon of storage

Savings

An average solar hot water system can prevent 3,400 pounds of greenhouse gas emissions which is equivalent to around 4,250 miles per year of pollution free driving. In 20 years it adds up to 34 tons of emissions prevented.(rerc-vt.org)

The cost of the average system is for a PV $15,000-$30,000 and hot water system $8,000-$15000 however with spending less on your energy bill it will pay for itself in an average of 6 years! Incentives can lower the cost of a system by 70%

Fossil Fuels are a main cause of global warming

Where To Start

People may be aware of solar technology and its benefits, but may not know where to start when it comes to investing in their own system. It's actually very simple, all you need to do is make one phone call to a company and they will help you with questions and decisions that best fit your home's application. You need no prior knowledge and the company will walk you through each step, first starting with a site assessment at no charge. Below are just a few of the many local companies. They can provide further information on their services and taking the next step!

SunWind LLc.

Orleans, MA
Phone: 888-997-8694
Website: www.sunwindllc.com/

New England Breeze

Hudson, MA
Phone: 978-567-9643
Website: www.newenglandbreeze.com

Advanced Energy System Development

Wellesley, MA
Phone: 617-775-1720
Website:
www.advancedenergysystemsusa.com/

Wind Data Sheet

Wind Energy For Homeowners

- Two types of turbines are available for the home, vertical axis (above) and horizontal axis (right)
- Vertical axis turbines can generate power with wind blowing in any direction where as horizontal axis turbines cannot

- Wind turbines harvest wind energy turning wind into electricity
- A household wind turbine can supply around 60% of a home's electricity
- The average return on investment is between 5-7 years
- Most turbines generate power in 8-10 mph winds
- Some turbines can start generating power as low as 6.5 mph (cut in speed)
- Average wind speed for an area can be found online (Mass GIS)
- A full 12-15 month wind study with an anemometer should be conducted before purchasing a wind turbine
- A residential sized wind turbine is no noisier than an average refrigerator

EcoTarium
science.nature.explore.connect.
222 Harrington Way Worcester, MA 01604
508.929.2700

Worcester Polytechnic Institute 1865 WPI
Bill Huard, Chris Massa,
Mike Szkutak, Nick Workman

Appendix K: Additional IQP Resources

Auburn, Massachusetts Wind Feasibility Study
By: Kyle Boucher, Justin Guerra, and Bryan Watkins

The purpose of this IQP was to produce a "second look" and assessment of the wind energy potential at a specific site in Auburn, to establish constraints and criteria, and to complete a cost-benefit analysis. Characterizing the site's wind energy potential required; researching Auburn's energy needs, interacting with the town chair, background research of the issue, and performing a trade study of wind turbines. To establish constraints and criteria, we examined social constraints such as; potential problems with neighbors, access road and entrance locations and anemometer placement. For our cost-benefit analysis, we studied different project implementations in terms of the turbine height, blade length, generator size, installation complexities and planning, and wind speeds. Through all the steps of this process we coordinated our work with the Auburn Wind Turbine & Alternative Energy Committee as well as the WPI Auburn Wind MQP Team.

http://www.wpi.edu/Pubs/E-project/Available/E-project-050410-081256/unrestricted/Auburn_Wind_IQP_Final_5-1-10.pdf

Winds of Worcester
By: Nicole Cahill, Michael Ghizzoni, and Jonathan Lo

This report outlines an extensive study done at Worcester Polytechnic Institute about the feasibility of a wind farm in Worcester County, MA. Technical aspects, potential locations, social implications, environmental impacts, political support and economic impacts are each comprehensively examined to determine whether a wind farm would be a possibility for this area. The report is concluded in a discussion on the tipping point of wind power both in Worcester and in the U.S.

http://www.wpi.edu/Pubs/E-project/Available/E-project-050509-134938/unrestricted/WindsofWorcester.pdf

Wind Power Sustainability in Worcester, Massachusetts
By: Christopher Kalisz, Calixte Monast, Michael Santoro, and Benjamin Trow

The goal of this project was to identify criteria needed to determine the sustainability of potential wind turbine sites in Worcester, Massachusetts. The report first discusses physical, environmental, economic and social factors that affect the sustainability of potential wind power sites. We then completed a case study for a site in downtown Worcester, directly applying the criteria. Our hope is the project will raise local awareness of renewable energy and illustrate the practicality of a clean energy project.

http://www.wpi.edu/Pubs/E-project/Available/E-project-031405-135030/unrestricted/IQPWND1.pdf