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THE NATIONAL MUSEUM OF SCIENCE AND INDUSTRY OF LONDON WIND ENERGY EXHIBIT

An Interactive Qualifying Project Report
submitted to the Faculty
of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfilment of the requirements for the
Degree of Bachelor of Science
by

Laura Ann Domey

Laura A. Domey

Wendy Kogel

Wendy E. Kogel

Benjamin E. Newton

Date: 2 March 2000

Approved:

Holly K. Ault

Joel J. Brattin

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3. Museum

ABSTRACT

The National Museum of Science and Industry in London proposes to build a physical and virtual Energy Gallery. As a team we researched wind energy, the National Curriculum, and public knowledge to develop ideas for the wind energy component of this gallery. Our ideas underwent an evaluation and revision process to ensure their quality and effectiveness. We presented the final version of these exhibit ideas to the museum for use in the Energy Gallery.

EXECUTIVE SUMMARY

The National Museum of Science and Industry in England is in the process of developing an Energy Gallery. The museum plans to dedicate a section of this gallery to wind energy. Our team has designed and developed a variety of exhibit ideas for display in this particular component of the gallery. We have also created virtual exhibits for the museum's web site. These ideas have undergone an evaluation process to ensure their quality and effectiveness. We revised many of our ideas upon the completion of the evaluations, and we presented these ideas to the museum for use in the upcoming Energy Gallery.

Our team researched wind energy to determine the content of our exhibits. We also investigated the subjects covered in the National Curriculum to establish what our exhibits must cover to serve the school population. In addition to this research, we administered a questionnaire to gauge public understanding of wind energy. The combination of this information led to the development of our exhibits.

We established four content categories, each containing a different message about wind energy. We used these categories to design our exhibits to ensure that we have properly conveyed what wind energy is and how it affects the world around it. The first category is *The Way it Works,* which contains exhibits that explain the mechanical and electrical aspect of wind energy. *Climates and Countries* shows how different climates and geography affect the use of wind energy. *Time Periods and Lifestyles* explains the history of wind energy. *Environmental Impacts* covers the positive and negative aspects of using wind as a source of energy.

These categories guided us in the creation of our exhibits. The exhibits we have created can be classified as a physical or virtual exhibit. Physical exhibits are displayed in the museum. The virtual exhibits are accessed via the World Wide Web. Our virtual exhibits contain some similar ideas to our physical exhibits, but they also include exhibits that cannot be seen at the museum. Similarly, the physical exhibits have many components that are available only to those visiting the museum.

Our team created a series of exhibits, each containing a unique message about wind energy. These exhibits went through a preliminary evaluation with our liaison, Sophie Duncan. Her expertise in this field provided us with insight in designing exhibits. She made many suggestions to improve our exhibit ideas. Using these suggestions, we revised our ideas and eliminated the ones that would not be suitable for the Energy Gallery.

The remaining exhibit ideas went through a second round of evaluation to further their improvement. The team of museum staff involved with the Energy Gallery provided another means of evaluation. We presented them with five of our exhibit ideas, and they gave us constructive feedback on these ideas. The exhibits then went through another revision process.

Exhibits cannot be tested with museum visitors unless a physical model has been created. We chose two of our exhibits to undergo further testing. We have created a virtual mock up of these ideas, and we tested them with visitors.

Where in the World is the title of one such exhibit. It educates the visitor about how different countries use wind throughout the world. The visitor has the ability to choose the location of a wind farm on a large globe, which results in the appearance of information regarding that particular farm.

The other exhibit our team tested with museum staff and visitors is the *Time Period Matching Game*. This exhibit allows the user to gain an understanding of the different time periods associated with different wind machines and what the jobs of the different wind machines was. The user is given the task of matching a wind machine with the appropriate time period. Correct answers result in a display of information about the use of wind machines in this time period.

Upon completion of this phase of testing, our team conducted its final revision process. We then wrote up all of our exhibits to give to The Science Museum. Our team added the virtual component of our exhibits to the wind energy component of the museums' web site.

Our team has developed nine final exhibit ideas that together explain what wind energy is and how it affects the world. The Science Museum used these ideas in their creation of the Energy Gallery. The virtual exhibits we have created have been implemented and will serve as a model for the remaining parts of the Energy Gallery's web page. Our methods of evaluation and revision have allowed us to improve upon our exhibits and therefore provide the museum with an array of designs to use.

ACKNOWLEDGEMENTS

We would like to thank Sophie Duncan, our liaison to the National Museum of Science of London, for helping us develop our exhibits. We would also like to thank the rest of the energy team, including Paul Davis, Claire Bonham-Carter, and Allen Morton for helping us test and improve our exhibits. We also thank the visitors of the National Museum of Science and Industry for their help.

We would also like to thank our advisors, Professor Joel J. Brattin and Professor Holly K. Ault, for their help and guidance, as well as Worcester Polytechnic Institute and Paul Davis for providing us with the opportunity to complete our IQP abroad. Finally, we want to thank Jennie Hawks for allowing us to stay at her cottage while we visited the Swaffham wind turbine.

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1 INTRODUCTION

The National Museum of Science and Industry in London is building a new Energy Gallery. The gallery will serve to educate people about different energy technologies that have shaped societies over time. The gallery will explore three fundamental questions. The first of these questions is 'Why is energy important?' The second is 'Where does energy come from?' The final question is 'Will there be enough energy for our future uses?' The museum proposes to have three teams of WPI students working on different energy technologies to be displayed in this gallery.

Our team created a proposal for both physical and virtual wind energy exhibits, which will make up an integral part of the gallery in the museum and the accompanying web site. We accomplished this by focusing on four main areas. The first topic is *The Way it Works*, which explains the mechanical and electrical aspects of how wind machines work. The second topic area is *Time Periods and Lifestyles*, which informs visitors about how the different types of wind machines affected people's lives. *Climates and Countries* is our third topic, which is devoted to where wind machines are used and why. Our final topic is *Environmental Impacts*. This section includes information on how wind machines positively and negatively affect the environment. Our exhibits cover both the positive and the negative aspects of wind energy, so that visitors get a complete picture of how wind energy affects the world around them. In order to accomplish this task, we sought both visitor and staff opinion of our physical and virtual exhibit designs to make sure that the exhibits are designed effectively. The completion of our project resulted in a finished proposal for both the virtual and physical wind energy exhibits.

The wind energy portion of this gallery will serve to educate the museum's visitors on what wind energy is and how it affects their lives. To accomplish this task successfully the exhibits must describe two different types of wind machines, windmills and wind turbines, and how they work.

Wind machines have made life easier for people all over the world. In general, people are more interested in learning about wind energy if they understand how it affects their lives. To show people how wind energy affects their lives we are going to show how wind energy has affected different cultures.

The supply of fossil fuels is gradually being depleted, leaving the world with the problem of finding new energy sources. Wind energy has the potential of being an important source of energy in the future. The museum exhibit will point out some advantages and disadvantages of wind energy as a primary source of power in the future. It is also important to discuss the environmental effects wind turbines have on their surroundings as well as how effective they are in generating power in different geographical locations, allowing us to understand how wind energy shapes the world around us.

A major goal of these exhibits was to keep people's attention long enough for them to learn about wind energy. Interactive exhibits are an effective means of holding the viewer's interest. The Energy Gallery will include a variety of hands-on activities to educate the museum's visitors in an entertaining way. Our team proposed ideas for interactive exhibits about wind energy.

Computers are important tools for conveying information, and therefore we also proposed ideas for an interactive computer exhibit. We designed a web page dedicated to wind energy to be added to the science museum's energy exhibit web page. The purpose of this web page is to educate the museum's virtual visitors. The proposed exhibit design allows visitors to explore and learn about the world of wind energy in the museum of science or on the web.

2 BACKGROUND RESEARCH

2.1 History of Wind Energy

Many countries and civilisations have used wind as a source of energy throughout time. It has provided a means for performing many different tasks including generating electricity. Wind power is becoming increasingly important as the world depletes the supply of fossil fuels currently used to generate electricity. Society has used windmills and wind turbines to harness wind in order to provide the world with power.

2.1.1 History of Wind Mills

The origin of the first windmills is unknown, but according to Richard H. Hills, author of *Power from Wind,* they did exist in Persia as early as the tenth century. In any case, windmills have played a crucial role in many societies. They have influenced the world because of the energy they provide to both homes and businesses (Kovarik, Pipher, & Hurst, 1979 and Hills, 1994).

Windmills have a variety of uses and have been implemented in many different ways. By the fourteenth century, windmills had spread throughout Europe including England. They were primarily used to grind grain in Europe. They spread rapidly throughout Northern Europe at the end of the twelfth century and gradually spread into the south of Europe. Eventually, people discovered many additional applications of windmills. Using wind to pump water was one of its earliest applications, appearing in the early fifteenth century. Additional uses include powering machines, making paper, crushing sugarcane, sawing timber, and pressing oil from seeds (Gipe 1995 and Cherremisinoff 1978).

2.1.2 Functions of Wind Mills

In simple terms, windmills transfer the force of the wind into machines designed to perform specific tasks. With a variety of tasks to perform, windmills come in different shapes and sizes. Historically, there have been three main types of windmills, and the way they work differs. However, some basic features are common to all of them. One such feature is the rotating sails, which collect the wind. There is always a device that turns the sails to face the wind in order to ensure that the mill gathers the most amount of wind, therefore generating the greatest amount of power possible. If the sails did not turn to face the wind the windmill would only operate when the wind came from a certain direction. There is also inner machinery that converts the wind to power for grinding grain, pumping water, or whatever other applications the windmill may have.

2.1.3 Types of Wind Mills

The post mill is one of the three main types of windmills. Conveniently, it turns to meet the wind from any direction, and it is used to grind grain and pump water. The post mill, made of wood, contains a large upright post. This post supports the sails and machinery that revolve about it. The post is a vertical

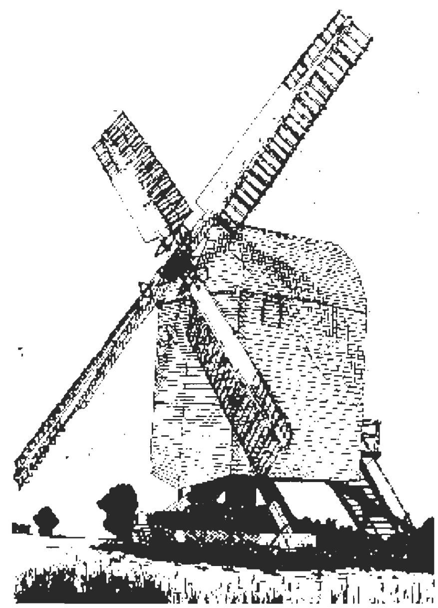

Figure 1 - Post Mill

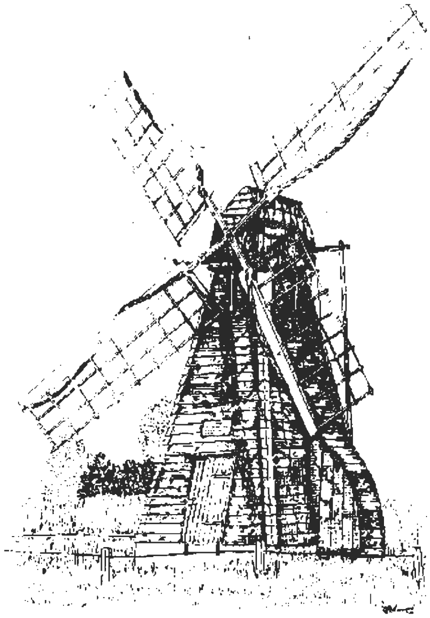

Figure 2 - Tower Mill

axis pivot point upon which the entire apparatus can turn. Figure 1 shows a typical post mill.

The Dutch introduced the tower mill. Significantly larger than the post mill, it can withstand stronger winds. It can be built to any height and contain many floors for storage. The tower mill is also stationary with the exception of the top, and is usually made of brick or stone. Figure 2 depicts a tower mill.

The third type, a smock mill, looks like a smock, or triangle shaped figure, and differs from the other mills because it is made of wood. The smock mill is structured similarly to the tower mill, except it has a moving cap on top. The main difference between the smock mill and the tower mill is the materials they are made of. The smock mill is made of lighter materials and therefore the construction was lighter. The tower mill was sturdier though. The smock mill is designed to grind grain (Brown & Brown 1977). Figure 3 shows a common smock mill.

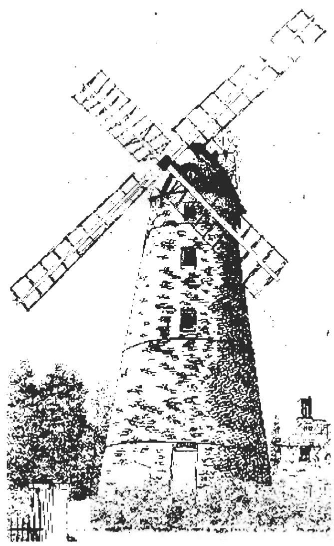

Figure 3 - Smock Mill

Windmills are found all over the world. In Islamic cultures windmills crush sugarcane and grind corn. In Denmark, windmills power milling or threshing machinery. By the early 1500s wind was also pumping water from wells to irrigate gardens. Railroads in America made use of windmills to fill the water tanks of steam locomotives in the eighteenth century. It was also common practice to use windmills to pump water for households and livestock. Many people who did not have central water systems used water-pumping windmills to bring running water into their homes and allow them to have working water closets (Kovarik, Pipher, & Hurst 1979).

2.1.4 Wind Generators

The idea of harnessing wind to accomplish a variety of tasks led people to investigate the production of electricity with wind. William Thomson, who was a physicist and electrician, was the first to propose the idea of using wind to generate electricity. He addressed the British Association for the Advancement of Science in 1881 with his idea to create electricity with wind power. He was concerned that windmills were not designed to accomplish this task. He also thought that cost would be a problem so he never actually developed a wind machine to produce electricity, but he did give the idea to others (Hills 1994).

In America this idea seemed very promising to Alfred Wolff, Joseph J. Freely, and George E. McQuestion who set up a small scale, wind powered, electricity-generating plant in the late 1880's. Another man who was interested in this idea was Charles F. Brush. He erected a windmill to provide power for experiments as well as a source of lighting his mansion. He built this in 1890 and it contained generating equipment mounted in the body. This generating equipment could charge 408 secondary battery cells in his basement (Hills 1994).

Professor Paul La Cour was placed in charge of an experimental test station in Denmark in 1891. This test station was designed in the hopes of discovering a way to provide electricity to Danish farms using the wind. In the following year England installed its first electricity producing wind machine. This machine was made in America and it operated a lighting plant in London (Hills 1994).

Dew Olive of Texas erected a large wind generator at the San Gorgonio Pass in Southern California in 1926. This generator failed as a result of financial difficulties. The French followed this idea and erected a two bladed machine at Bourget in 1929 (Hills 1994).

Another important development in wind generators was by Marcellus Jacobs who designed wind-generating farms, and installed them all over the world including North and South America, Antarctica, and Arabia between the years of 1931 and 1957. These farms were created to produce electricity in areas where there was a lot of wind. However, these wind generators were not ideal for producing electricity because they could not supply enough power. The generators designed by Jacobs produced between 2500 and 3000 watts of power. Since this did not provide enough power to produce an adequate amount of electricity for homes and businesses, they were used to charge batteries (Kovarik, Pipher, & Hurst 1979).

2.1.5 Wind Turbines

This failure of these wind generators to provide a major source of electricity led to the development of a more advanced wind generator called the wind turbine. In 1941 Palmer Cosslett Putnam developed a wind turbine on Granpa's Knob in Vermont. This turbine was very important because it was the first time a windmill had been connected directly on line with an alternating current grid system of an electricity supply company through a generator. It was designed to create 1250 kilowatts of power, which would light a small town. It was designed to supply power to homes when the wind was high. When the wind was low, the power company provided the needed energy, and in exchange, the wind turbine would supply the power company with the excess energy created during a period of powerful wind (Hills 1994 and Gipe 1993).

The turbine is comprised of a propeller and an electric generator usually perched on a tall support structure. The result is a clean and renewable source of electricity. Wind turbines generate electricity when the wind reaches a certain speed, which varies depending on the turbine. If the wind is below this speed no energy will be produced. They are each designed with different threshold speeds. The turbine was designed in the hopes of being competitive with other sources of electricity. National Aeronautics and Space Administration (US agency) played a role in constructing a turbine. NASA constructed a 100-kilowatt wind turbine with a propeller that was 125 feet in diameter. This wind turbine only generated electricity when the wind speed was above eight miles per hour. The Energy Research and Development Administration of the United States also contributed to the development of turbines. The wind turbine illustrated that wind could be a viable source of power (Kovarik, Pipher, & Hurst 1979).

World War II virtually stopped the progress of wind turbines. After the end of this war there was renewed interest in turbines in England. In 1950 a wind turbine was installed in Orkney. This was 23.77 meters high and had three blades as opposed to Putnam's two. In 1982 on Fair Isle, England a three-bladed fifty-kilowatt generator was installed with a rotor of diameter of fourteen meters. It has reduced electricity bills and prevented the island from the fear of being cut off from essential oil supplies (Hills 1994).

2.2 Current Technology

Today, windmills and wind turbines harness wind energy for many purposes such as generating electricity to power homes, supplementing utility power, and charging remote power storage batteries. Many people are considering wind energy as an alternate source of power because it is a natural force that is powerful, nearly pollution free, and renewable. As fossil fuels become scarce, wind energy becomes a more popular source of power. By 1999, wind power was generating over 10,000 megawatts of electricity worldwide (Danish Wind Turbine Manufactures Association, 2000). That is enough electricity to power over 8,300 homes according to the Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS). RECS found that the average household in the United States consumed an average of 864-kilowatt hours per months during 1998 (Energy Information Administration, 2000). Compared to the electricity consumption of the entire United Kingdom, the 10,000 megawatts of wind power in operation in 1999 would supply nearly one quarter of the British Isles with electricity.

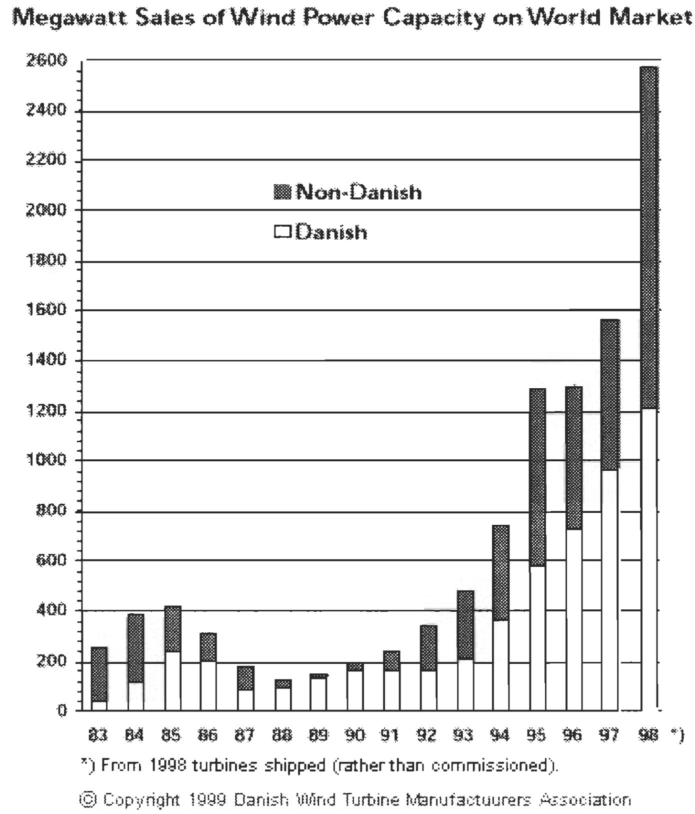

Figure 4 - Sales per megawatt from 1983 to 1999

This is based on the survey results of the Government Statistical Service that found the total available electrical energy in the United Kingdom during 1991 to be 343.4 terawatt hours (Government Statistical Service, 2000). The sale of wind turbines has increased dramatically in recent years as illustrated by the graph shown in Figure 4. This graph was published by the Danish Wind Turbine Manufacturers Association to show the increase in sales of their wind turbines (Danish Wind Turbine Manufactures Association, 2000).

Some of the disadvantages of using wind energy on a large scale are the noise it generates, the severe effects on the aesthetics of the surroundings of a wind farm, and the harm it can cause to wildlife and people. The need for new sources of energy is leading researchers to investigate ways of emphasising the positive aspects of wind energy and finding ways of controlling the negative aspects (Gipe, 1995).

2.2.1 The Turbine Propeller

The propeller is a key component to an efficient wind turbine. The cross-section shape of the propeller (or airfoil) is responsible for converting the forward motion of the wind into rotational motion of the turbine shaft. This discussion refers to the "top surface" and "bottom surface" of the airfoil. If one were to view the cross section of the airfoil while the propeller was on the turbine, the top surface would be the surface facing forward, or into the wind. Propeller airfoils work by the same principle as an airplane wing airfoil works. The shape of the top and bottom surfaces generates a lift force as air

Figure 5 - Air Flow

passes over and under the blade. When viewing the cross section, on the top surface, the path from the leading edge to the trailing edge is a longer distance than the path from the leading edge to the trailing edge on the bottom surface. As air passes around the blade, the air that is directed over the blade has a farther distance to travel than the air that passes under the blade to reach the trailing edge. The air moving over the blade travels faster than the air under the blade causing a pressure increase under the blade and a pressure decrease over the blade. This difference in pressure draws the blade forward (or upward in the case of an aircraft wing.) When two or more blades are oriented in a radial shape, like that of a propeller, the net result is a force that pushes each blade around the shaft of the propeller in a spinning motion.

Unfortunately, lift is not the only force generated by an airfoil as air passes over it. With any body moving through air, there is always air resistance caused by friction. The force of friction on a wing or blade is called drag. This force can slow a propeller down and cause noticeable losses in power output of a wind turbine. A measure of the efficiency of a propeller blade is the lift to drag performance ratio (Giguère, 1998). If a propeller's drag, combined with the mechanical bearing friction, is greater then its lift, the propeller will not function.

Propeller blades can be manufactured from a variety of materials. Historically, this material has been wood. Wood is known for its high endurance to mechanical stress and fatigue. Blades can be carved directly from a solid block of wood, or from a block of laminated wood, or they can be moulded using extremely thin slices of wood called veneer. In the 1970s, aluminium blades were used in some wind powered battery charger applications. However, drawn aluminium does not endure the fatigue that a blade on a propeller experiences. Today metal is almost never used, as metal fatigue can cause a blade to crack or break. Fatigue is analogous to what happens when a thin piece of metal is bent repeatedly until it breaks at the flex point. Other materials used today are fibreglass (glass-reinforced polyester, or GRP) or other man-made composites (Gipe, 1993).

2.2.2 The Generator

With the propeller acting as the source of rotational energy, a device is needed to convert this energy to electric power. This is the function of the alternator, or generator. The term alternator refers to a device that produces AC (alternating current) power and the more general term, generator, refers to a device that produces AC or DC (direct current) power. There are three options for transferring the rotational motion from the blades to the generator. The first option is a direct drive. The spinning rotor (propeller and drive shaft) is directly connected to the generator. The drawback to this approach is that the generator must be designed to operate at the comparatively slow rotational speeds at which propellers typically spin. The average speed of most rotors is between 19 and 34 revolutions per minute (Bodamer, 1999). The second and third options employ a transmission. The purpose of a transmission is to increase, or step-up, the rotational speed of the generator drive shaft. The second option is a mechanical transmission, which consists of a gearbox, chain drive, or belt drive. The third option is the hydraulic transmission, which uses hydraulic fluid through pumps to transmit the energy from the rotor to the generator (Gipe, 1993).

2.2.3 Protection from Loss of Load

During normal operation, the electricity generated by a wind turbine is used up, because there is an electric load attached to the turbine. This load could be a collection of appliances in a home, a utility power grid, or a battery to be charged. The existence of this load provides rotational resistance in the generator. When the load is removed, this resistance disappears and the generator is allowed to freewheel. The loss of load can occur due to different factors depending on the application. If a turbine is charging a battery, the load will slowly drop off when the battery is finished charging. If the turbine is part of a wind farm and is connected to the utility power grid, a power outage will drop the load from the generator. If a turbine is operating when any of these events occur, the rotor will begin to spin at dangerously high rates. For this reason, a wind turbine must be fitted with an emergency protection device to prevent damage to the rotors and drive train in the event of the loss of the load.

There are two methods of protecting against this type of damage: mechanical brakes and automatic furling. Mechanical brakes can be applied to the drive shaft as soon as the turbine detects that its load has been dropped. Furling, on the other hand, is a means of positioning the blades of the rotor out of the path of the wind so that rotation stops. If the blades are positioned parallel to the direction of the wind, they stop producing lift and rotation stops (Gipe, 1993). Positioning the blades in this manner can be done in several ways. Some turbines have outboard tail fins on a long boom that extends from the back of the turbine. When a special electric circuit in the turbine detects a load loss, that fin is rotated ninety degrees horizontally. This will force the entire turbine to rotate about the vertical axis of its mast such that the plane of the propeller is positioned parallel to the direction of the wind. Another method of furling involves a mechanical drive that rotates the propeller upwards when the load is lost so that the plane of the propeller is parallel to the ground and the direction of the wind. The third method rotates each blade of the propeller individually instead of moving the entire turbine. Each blade is rotated ninety degrees such that each becomes parallel to the direction of the wind. Another purpose of brakes and furling is to protect the turbine during periods of particularly fast winds (Gipe, 1993).

2.2.4 Support Structure

Whether a turbine is part of a vast wind farm or is used as a stand-alone generator, a large wind turbine needs a safe, reliable, and visually unobtrusive support structure. There are two distinct categories of wind turbine towers: guyed towers and freestanding towers. Cables, or guy wires, support guyed towers while freestanding do not require any additional support. The cables supporting a guyed tower are attached near the top of the tower and anchored to the ground at a set radius around the tower. The structure of a freestanding tower is typically more heavily reinforced due to the lack of external support. Two types of freestanding towers exist. The first is the lattice tower. A familiar example of a lattice tower is the Eiffel Tower in Paris, France. The second type of freestanding tower is the tube or pole tower. The structure consists of

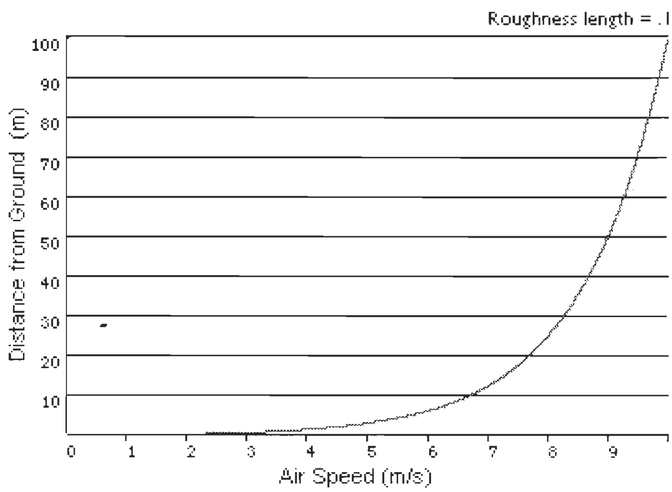

Figure 6 - Turbine Height vs. Wind Speed

a heavy tube or pipe that supports the turbine. Freestanding towers usually rely on a massive cement footing for support and stability. Guy towers rely on several smaller cement or stake footings at the base of each guy wire (Gipe, 1993). Towers must be designed to support not only the force that the wind will exert on the turbine, but also the force that the wind will exert on the tower itself, the weight of the turbine, and the weight of a support crew and support tools that may be necessary during maintenance.

The height of the tower is key to its power output efficiency. Until recently, the common thought was simply to raise the turbine off the ground. Today, the general rule of thumb is the higher the tower, the more electrical power the turbine will produce. Accordingly, the average height of turbine towers has gradually increased in recent years. The biggest factors in height versus power output are wind speed and turbulence. It is crucial to get the rotor above obstacles that may impede the flow of the wind, such as trees, buildings, or hills. Once this is accomplished, one must consider wind turbulence. Even in an environment of flat plains where there are no obstacles, it is important that the turbine be far from the ground. When wind blows over the ground it is disturbed by the earth's imperfections. These disturbances can cause vibrations in the blades of the turbine, which can lead to added friction in the drive shaft, slower rotation speeds, and unwanted maintenance problems (Gipe, 1995). These imperfections in the surface of the earth are described by the roughness factor. A perfectly flat surface, like that of a calm body of water, has a roughness of about 0.1. A very rough surface, like that of an area with many trees or buildings, has a roughness of three or four. A typical roughness for a grassy field is around one. Figure 6 depicts the change in wind speed vs. the distance from the ground. In this graph, the horizontal axis is the wind speed and the vertical axis is the distance from the ground of the turbine hub. One can see that as the distance from the ground increases, the wind speed increases. However, as the asymptotic nature of the graph suggests, after a certain height threshold is reached, the added efficiency gained by increasing the height diminishes drastically (Danish Wind Turbine Manufacturers Association, 2000).

2.2.5 Mass Power Generation

One can find wind power generation plants, or wind farms, in a variety of sizes, from a small cluster to a vast array of hundreds or even thousands of wind turbines. Gipe defines a wind power generation farm as "any cluster of wind turbines used for bulk generation of electricity" (Gipe, 1995, p.15).

A group of advocates that wanted to promote wind energy as a more conventional source of electricity rather than a novelty coined the term "wind power generation plant." At the same time, a group of people was interested in maintaining the association between the preservation of the environment and clean wind power, which is where the term "wind farm" arose. Today, the accepted name is most often "wind farm" (Gipe, 1995).

Wind farms must be supplied with an abundant source of wind in order to maintain efficient output. The typical operating range of wind speed for most turbines is five to twenty-five meters per second (Bodamer, 1999). To ensure a constant supply of wind, engineers must consider the location and the orientation of the turbines in great detail before they construct a wind farm. One can install a wind farm in a very hilly area as effectively as on a flat plane. The orientation and layout of the turbines depends heavily on the terrain in which they installed. Turbines mounted on steep hillsides or flat plains are best arranged in a grid formation. Where sharp ridges are available, mounting turbines along the peak at alternating heights above the peak is very efficient. This stepped array acts as a "wind wall" not unlike a dam in a river. Other optimal locations include areas with hard linear features such as pasture lines, dikes, or straight coastlines, which directs wind in a straight path. Off shore wind farms have also been implemented with success (Gipe, 1995).

2.2.6 Wind Turbine Efficiency

One of the major sources of complaint from sceptics of the wind energy is that of wind turbine efficiency. With each year, wind turbines become more efficient, capable of producing more and more electric power per turbine. The most recent development has been the commissioning of a number of 1.5-megawatt turbines. These are the largest and most powerful wind machines to date. One such turbine is the 67-meters tall, 1.5-megawatt Enercon E-66, capable of supplying enough electricity for 3,000 people. Standing in the Norfolk town of Swaffham, this turbine supplies enough electricity for half of the town's population (Simons, 1999).

A key indicator of a wind turbine's efficiency is the payback period, which is the amount of time it takes the turbine to produce the amount of energy that was required to manufacture, install, maintain, dismantle, and scrap it. Typically, today's modern wind turbines have a payback period of two to three months. Even the older 55-kilowatt turbines of the 1980s reached their payback period in approximately six months. The Danish Wind Turbine Manufacturers Association arrived at these results after measuring the energy spent during manufacturing, installing, maintaining, dismantling, and scrapping a single turbine (Danish Wind Turbine Manufactures Association, 2000).

2.2.7 Aesthetics and Public Acceptance

A major factor when planning the construction of a wind farm is public acceptance. The machines may reside next door to a rooted community or in someone's back yard. Part of this public acceptance lies in the appearance of the structures. If the wind farm is aesthetically unpleasing, the community will reject it.

The design of a farm must include the final appearance of the farm. To be aesthetically pleasing, all of the turbines of a wind farm must have a uniform appearance. Several steps can be taken to achieve the look of uniformity. Though the turbines do not have to be identical, they should be painted the same colour, they should be situated at the same height, they should have the same number of blades on the propeller, and they should all spin in the same direction. In addition, the general design of the tower, nacelle, which is the generator covering, and rotor, should all be visually similar (Gipe, 1995).

Besides good appearance, there are other ways of raising public acceptance of a wind farm. The area should be free from visible power lines, transformers, substations, or other ancillary buildings. Some ways to do this are to install transformers in the base of the support structure and to bury power lines. If an auxiliary building must be built, it should be disguised with façades to make it match the architecture of the buildings in the area using local building materials such as masonry or old timber (Gipe, 1995).

The design of the wind turbine itself should be sleek in appearance, unlike the early American turbines that appeared rickety and angular. Tube style supports, aerodynamic turbine housings, and nose cones for the rotors are all ways to improve the appearance of the structural design. A turbine should never be left standing without its nacelle. When viewers see that the internal components of a turbine are exposed, they believe there are costly maintenance problems. That is not the only trigger that makes a wind turbine appear problematic and costly. If a wind turbine is standing idle, not spinning, then it is perceived to be broken, inefficient, and a waste of money. Even if the wind is not strong enough to produce useful amounts electricity, the turbines should be allowed to freewheel so that they appear to be useful (Gipe, 1995).

Most wind farms employ security lights to protect the turbines during the night. However, this draws unwanted attention to the farm making it stand out in contrast with the surroundings. An effective way of avoiding this problem is to use motion sensitive lighting. Many wind turbines are tall enough to require aviation-warning lights. The only way to avoid them is to avoid building farms close to airports (Gipe, 1995).

2.2.8 Wind Farm Safety

Visual appearance aside, wind farms can pose other problems to the people inhabiting the area. Safety hazards caused by wind turbines are a major concern to many groups that oppose wind farms. Though the odd situation can occur, Gipe claims, wind turbines do not pose a safety threat to society (1995). He says that aside from the over-curious individual that climbs a wind turbine's tower, no one has ever been hurt by a wind farm. Regardless, signs are still posted to warn the public of danger near most wind farms in the United Sates.

2.2.9 Noise Pollution

Noise pollution is a serious concern of wind farm mangers and planners. In general, as wind speed through the rotors of a farm increases, so does the noise that the farm produces. For a particular wind turbine (the Bonus Combi) described in Gipe's Wind Energy Comes of Age (1995), the sound pressure level is 92 Decibels (A) at a wind speed of 4 meters per second. At the same distance and a wind speed of 15 meters per second, the sound pressure level is 104 Decibels (A). Noise originates in turbines from both mechanical and aerodynamic sources. Some steps can be taken to reduce the noise. The shape of the blade can be adjusted so that the trailing edge is as thin as possible. The blade tips should also be aerodynamically stable, as they are a large contributor of noise. Another way of reducing noise is to reduce rotor speed by increasing the gear ratio of the transmission to get the same power output from a slower turning blade.

2.2.10 Small Scale Uses

Wind energy can be very useful on a much smaller scale than the large wind farms of mass power generation. There are wind turbines small enough to be carried on horseback. Unlike their giant cousins that have rotor diameters up to 66 meters, small portable turbines can have a rotor diameter of just one meter. They can be adapted to do more than just produce electricity for direct use. By 1995, 17,000 wind turbines were operating in California in large farms. However, another 5,500 turbines were operating in the area independently in less conspicuous applications (Gipe, 1995).

Individual wind turbines have many specific applications. They are most often implemented where utility power is unavailable or the cost of installing utility power cannot be justified. Such applications include mountain top telecommunications sites, remote villages, homesteads, and remote pumping stations. A growing application for individual turbines is their use by homeowners, mostly in the United States, as an alternative to expensive utility power. Wind turbines can lower the consumers' utility bills. Small turbines are also being used to pump water mechanically. Hybrid systems utilise turbines to charge batteries for more reliable power availability. Another use for hybrid systems includes the addition of a second generator powered by an internal combustion engine (Gipe, 1995).

These smaller, but often invaluable, wind turbines can be found worldwide. In 1995, the government of New South Wales subsidised stand-alone power systems using wind turbines to power remote cattle stations in the Australian outback. Third world countries have found wind power to be a cost-effective means of powering villages. Small wind turbines are often capable of supplying their needs. They are also used to pump drinking water. Two turbines may supply over 4,000 people with safe drinking water (Gipe, 1995).

2.2.11 Wind Machine Locations

Currently wind machines are used all over the world to grind grain, pump water, saw timber, and generate electricity. People have been trying to use wind to generate electricity for many years. In the mid 1990s this dream started to become feasible on a large scale.

California has been known for its wind farms since the 1980s when the number of wind turbines grew drastically. In California there are three main wind farms. Altamont is located in the north and generates one-third of the wind power. Tehachapi is located in the south and generates one-half of California's wind power. The third wind farm, which generates most of the remainder of California's wind power, is in San Gorgonio. By the mid 1990s California was annually producing three terawatt hours of electricity. California imported 50% of their turbines from European countries primarily from Denmark and Germany (Gipe, 1995).

Germany has come a long way since the 1980s. Since then it has been installing new turbines at the rate of 200 megawatts of electricity per year. In 1994 Germany's wind operating capacity was 500 megawatts. The largest wind farms in Germany are located in Lander of Nidersacchsen in lower Saxony, Schleswig-Holstein in the north, and Mecklinburg-Vorpomern by the shoreline. Niedersachsen and Schleswig-Holstein dwarf wind programs anywhere else in Europe and North America. In 1995 each location committed to building enough turbines to produce 1000 megawatts. Germany is also known for the turbines it manufactures. Bonus, Vestas, Nordtank, and NextGeneration dominated the German market in 1995 (Gipe, 1995).

France initially experienced some difficulty in beginning to use wind power. This is because the Electricite de France (EDF) controlled the market and gave a low tariff. France started a program in the 1980s, which failed and then launched it again in the 1990s with more success. In 1994 France built the first wind farm in Port-la-Nouvelle (southern France). It generates 5.1 million kilowatt hours annually. In 1995 near the Belgian border, France installed nine turbines in Nord-Pa-de-Calaid (Gipe, 1995).

Denmark has had a rich history in wind technology. Because most of the country is filled with farms, Denmark's wind technology has not developed through the government but through the agricultural industry. Between 1973 and 1994 wind turbines were installed in a boom throughout Denmark. In 1994 3,500 turbines produced 500-megawatts of energy. Wind turbines are not new to Denmark. In 1891 the Danish experimented with wind generating electricity. During WWI and WWII, the Danish used wind generated electricity heavily so that Denmark did not need to rely on importing oil from other countries (Gipe, 1995).

The British Isles are renowned for having some of the windiest cites in Europe. It is estimated that Britain is 28 times windier than Denmark. Even though Britain has great wind resources, it still took a long time for Britain to catch up to other wind powered countries. In 1989 the Thatcher Government started the Non-Fossil Fuel Obligation (NFFO) to aid the nuclear industry. Although the NFFO meant to aid renewable energy companies, the NFFO gave only 1% of the funds to them. In 1990 the NFFO started to help wind energy by creating a fifteen-year fixed price contract to encourage power companies to use renewable energy. By 1994 England and Wales were generating 565 megawatts of electricity and Scotland was producing 100 megawatts (Gipe, 1995). The most powerful turbine in England currently is the EcoTech wind turbine in Swaffham. This wind turbine generates enough electricity to power half the surrounding town with 1.5 megawatts of power. The turbine stands sixty-seven meters tall without the blades and 100 meters including the 33-meter long blades. The turbine stands as high as ten buses standing on end.

India has one of the fastest growing wind energy markets. In the mid 1990s India was installing more wind generating capacity than North America, Denmark, Britain, and the Netherlands. Some of the first wind turbines in India were installed in Okha in the province of Gujarat. These ten Vestas turbines stand fifteen meters high.

Italy's wind power is still developing. In the mid 1990s Italy started to build test sites to determine if wind power was a possible source of energy. On Sardinia, in Alta Nurra, the Italians constructed a 1.5 megawatt turbine along with several smaller wind farms for testing. By the end of 1994 Italy was generating 20 megawatts of electricity. The Italian government is concerned with the environmental effects that wind power is going to have on Italy. Because of environmental impacts, the Italian government is trying to limit the number of roads that are built, and to ensure that the turbines are aesthetically pleasing (Gipe, 1995).

Greece, like other Mediterranean countries, has been slow to start using wind energy. By 1995 Greece had a 30-megawatt capacity. Studies show that Greece has the possibility to produce 14% of their electricity using wind energy. That would be 6.4 terawatts of electricity per year. In 1992 the Minister of Energy set a goal of 400 megawatts by 2000. The main obstacle to Greece's expansions of wind power is the state-owned Public Power Corporation's (PPC) unwillingness to interconnect with private energy companies (Gipe, 1995).

Unlike Denmark and the United States, Spain has been slow to build wind farms. This is due to the lack of utility financed contracts and the energy infrastructure of Spain. To encourage the development of wind power in Spain the European Community (EC) has provided Spain with funds. In time, Spain envisions 4% of their needed energy coming from wind power. The largest site of Spanish wind farms is southwest of Gibraltar, between Algeciras and Tarifa. This site serves 8 million people. In 1994 the

250 turbines were producing 30 megawatts of power, making it one of the largest concentrations of wind turbines in Europe (Gipe, 1995).

People have used wind machines for many different applications over a vast period of time. In the past, wind machines were used to grind grain, saw timber, and pump water. Today's society uses wind machines to generate electricity. Wind machines have been and will be an important technology in the development of society.

2.3 Museum and Web Exhibits

Museum exhibits must be adaptable to a wide range of visitors. A characteristic of visitors is that they are non-captive learners; they will remain at an exhibit only as long as it holds their attention (Hirumi, Savenye & Allen, 1994). Visitors come to museums to learn about new ideas, cultures, or technologies. When they leave they should feel full with the knowledge that they have acquired.

2.3.1 Physical Exhibit Development

Developing a physical exhibit takes a significant amount of time and planning. Museum staff must complete many steps before opening an exhibit. The exhibition development team must find at least one sponsor before the planning of a gallery starts. Once the team has found a sponsor, they can start to develop a story line for the gallery while locating additional sponsors. As the team develops the exhibition plans, more funding should be secured. The National Museum of Science and Industry does not seek funding for specific sections or exhibits of any gallery but for a gallery in general. This is done to insure that each topic will be presented equally and without bias. Each area of the story line is tested to make sure that it fits into the content and structure declared for the exhibit. When developing the exhibition, it is important to make sure that no single concept is emphasised in preference to another. This policy of the National Museum of Science and Industry to make sure that all subject matter is displayed equally and without bias. When designing each area of a gallery the museum staff makes sure to incorporate items from their collection. Next the gallery design is drawn up bringing together all the different exhibits, forming one overall story line. The final step in designing the exhibition is installing the objects into the gallery.

2.3.2 Visitor Attention Span

Even though galleries can take years to create, visitors to a museum will spend on average between 20 and 45 seconds looking at a typical display (Hirumi, Savenye & Allen, 1994). There are many things a museum can do to hold the visitors' attention longer, such as having interactive exhibits, creating a story to express the content of the exhibit, or displaying interesting or eye-catching objects. To engage a visitor's attention, the exhibit should be interactive and educational. Observations of visitors at museums show that they tend to stop and look at exhibits that move, make noises, or are tactile (Hirumi, Savenye & Allen, 1994). Many media contain an interactive aspect. Some examples are video recordings, computer programs, creation tables (allowing the visitors to build an object), touch tanks, or basic hands on activities. Each allows visitors to interact with the subject of the museum exhibit, and engages their attention longer. Though interactive exhibits can keep visitors' attention, it is also good for museums to have objects from their collections on display. These objects allow visitors to see the real item. Having original objects on display catches the visitors' eyes as they walk past and exhibit and draws them into the gallery. Because each visitor will look at a gallery in a different way, it is important to incorporate many different types of design aspects into each exhibit.

2.3.3 Exhibit Design Considerations

Designers of an exhibit must consider the durability of any objects they put in an interactive environment. If museum visitors are constantly touching, twisting, bouncing, or squeezing objects, the objects are subjected to wear. The key is to find objects that will stand up to visitor abuse for a long period of time. The San Diego Natural History Museum uses touch screens for their interactive videodisc displays because they are more durable than a normal keyboard. Touch screens are also beneficial because they do not require many skills to operate (Hirumi, Savenye & Allen, 1994). The level of skill and knowledge of the visitors is also important to consider. If the visitors cannot operate a device or understand the concepts in an exhibit, it will be of no use to them. The opposite is also true; if the knowledge level of the exhibit is too low the visitors' knowledge and understanding of the subject matter will not be increased (Hirumi, Savenye & Allen, 1994). When creating a gallery in a museum, the museum will pick a target audience for the gallery to be geared towards. The target audience should get the most out of coming to the gallery but it is still important for the museum to design the gallery so that all visitors will learn something new.

2.3.4 Design and Content Goals

Having a design goal is essential to exhibit development. This design goal should be the final picture and inspiration for the project (Carliner, 1999). The design goal helps the development team keep a common theme throughout the entire exhibition. Separate from the design goal is the content goal. The content goal describes the concepts that visitors should understand after they view an exhibit (Carliner, 1999). Our project concentrated on developing these two types of goals. We used these goals to design exhibits that educate the visitors about how wind energy is produced, how it has developed, and where the technology will bring us.

2.3.5 The Web and Human-Computer Interactions

When creating a virtual or web based exhibit the development team should follow the same goals, but the objects are pictures or video clips, not replicas, artefacts, or life-size dioramas. To create a web page that visitors will enjoy reading and learning from is a challenge. To help visitors' enjoyment and understanding of a web site, human-computer interaction (HCI) techniques must be followed. The goal of HCI is to allow designers to create an interface that does not distract users from the experience. Users should not have to interact with awkward or poorly designed interfaces that break the flow of the activity. They should feel at ease and in control of the interface at all times (Hilary, 1999).

There are eight golden rules of designing a good user interface. They are as follows: keep consistency, allow shortcuts for frequent users, offer informative feedback, design dialogs to yield closure, offer error handling, permit easy reversal of actions, support internal locus of control (that the users are in charge of the system), and reduce short-term memory load of the user (Shneiderman, 1998).

To be consistent, all fonts, colours, graphics, and styles should be the same throughout a web site. Everything should fit together and the user should be able to anticipate what he or she will learn about next.

People of different ages and experiences have different comfort levels with a computer. In order for their learning experience to be worthwhile, the users have to be comfortable with the interface. Young children learn better if they are kept active. To keep children active an exhibit must be naturally engaging and varied, but still relatively simple to understand (Harbeck, Sherman, 1999). However, adults may want more content and less activity in a learning situation. However, the adults also seem to like interactive exhibits because the exhibits give them a chance to play with science instead of just reading or hearing about it. Also important is the adjustment time users need to become accustomed to using a computer interface. Infrequent users of any interface will need help, whereas frequent users will not need help and could become frustrated if they receive it too frequently.

The system should not crash easily but instead deal with the user's errors in a constructive manner. This is accomplished by allowing users to reverse their actions. Another possibility is to have the computer offer suggestions to the users about how to complete a task. Most importantly, users need to feel in control of the situation; otherwise they will get frustrated.

In today's world it is important to make sure that disabled people will be able to read and understand a web site as easily as everyone else. *Bobby* is a web-based tool that analyses a web page to determine whether or not it is accessible to people with disabilities. The World Wide Web Consortium's (W3C) wrote The Web Content

Accessibility Guidelines, which sets the guidelines *Bobby* follows. A web site must follow a certain set of guidelines in order to be approved. It must provide text equivalents for all non-text elements. It has to provide summaries of graphs and charts. All information that is in colour must also be available without colour. It must clearly identify changes in the natural language of a document text such as captions. It must organise content logically and clearly. Finally, it must provide alternative content for features that may not be supported. *Bobby* is also useful because it analyses a web page's compatibility with different browsers. Although *Bobby* does not check the web page for all aspects of accessible web page design, it does provide suggestions about the areas it cannot effectively analyse (CAST, 1999).

Whether an exhibit is virtual or physical, it is important to keep the visitor happy and engaged in the subject. Exhibit design teams believe they have succeeded when their exhibits provoke thought and change beliefs (Carliner, 1998).

2.3.6 The Susie Fisher Group

The Susie Fisher group created a concept evaluation for a new Energy Gallery at the National Museum of Science and Industry in London. One of the goals of the Fisher group was to qualitatively explore visitors' understanding and interest in energy and energy issues. This included prior knowledge, attitudes, concerns, and misconceptions. They also wanted to gain an understanding of people's technical grasps of energy to identify issues that concern people about energy, and to find out people's expectations of what the Energy Gallery should contain. Fisher studied three different frames: children aged 11 to 12, parents of children aged 5 to 12, and independent visitors.

The Susie Fisher Group found that the visitors they talked to feel like they already know all there is to know about energy, even though they do not. They expect science museums to have exhibits on energy, but for the most part visitors do not expect to learn a lot from them. These visitors found the topic old and boring. They are tired of hearing about "doom, gloom, and hypocrisy" (Susie Fisher Group, Chart 6). They are also tired of learning how society is destroying the world by polluting the environment, digging up fossil fuels, and depleting the supply of non-renewable energy sources. Fisher says that to get people interested in the subject again, an exhibit needs to be interactive. Visitors want the exhibit to show how energy affects their lives and to challenge them to complete puzzles (Susie Fisher Group, Chart 45). The people Fisher talked to need to learn more about what energy is, how power is generated, what the risk benefit analysis is, how to balance supply and demand, how climate and geography affect the world, where energy comes from, and where it has come from in the past.

2.3.7 National Curriculum

In Great Britain the government sets up the National Curriculum so that all school children receive the same education throughout the country. The National Curriculum is broken down into several subsections known as Key Stages. Children between the ages of three and seven are members of Key Stage one. Seven to eleven year olds are members of Key Stage two. Children aged eleven to fourteen are in Key Stage three, while children aged fourteen to sixteen are in Key Stage four. There are other levels for secondary education as well as graduate and adult education. Each of the Key Stages has its own section in the National Curriculum devoted to declaring what information should be covered for each age group.

Each Key Stage contains a set of topics in each subject that the teachers should cover. The museum is focusing on Key Stages two and three in their development of the Energy Gallery. With this in mind, our team used the subjects in these Key Stages to guide us in developing our exhibits. Key Stage two contains such topics as friction and air forces, which we can relate to how blades work. Another topic in Key Stage two that we found useful was that students in this age range should know how to complete a circuit. For example, wind turns the blades of a turbine and the turbine then produces electricity, which then lights a light bulb.

In Key Stage three a student learns how frictional forces affect motion. They also learn about current, rotational forces, and energy sources. More specifically, they learn that electricity is generated using a variety of energy sources and they learn that energy can be transferred and stored. These topics are specific to ideas that we will cover in the Energy Gallery.

These subjects helped us to understand what students were learning in school. From this information we created a list of general ideas that we wanted to cover in the wind energy component of the Energy Gallery. The first idea that we thought was important was explaining how wind could be used to create energy. The second idea we found important was the history of wind power. The third idea was how different countries with different climates used wind power. The final idea was how wind affected the environment. We decided to create four categories to encompass these main ideas. We entitled them, *The Way it Works, Time Periods and Lifestyles, Climates and Countries,* and *Environmental Impacts.*

2.3.8 Wind Energy Gallery

The target audience for the Energy Gallery is Key Stages two and three, which includes children between the ages of seven and fourteen. Even though these children are not going to be the only visitors to the exhibition, we will gear all the exhibits in this gallery towards them. The museum draws a large portion of its visitors from school groups. Exhibits that target school groups must contain information pertinent to the National Curriculum.

Through the background research and questionnaire results we developed four main categories that all of our exhibits will fit into. The first area, *Climates and Countries*, includes topics discussing how geography affects climates and life styles. The National Curriculum is concerned with students learning about their world. This category will educate visitors about how wind technology affects everyone and how different cultures use the technology in different ways. *Environmental Impacts* covers all information about how wind energy affects the environment. This includes such topics as noise pollution, clean energy sources, and animal migration. When we researched wind technology we found that windmills and wind turbines affect their environment in both positive and negative ways. We thought that the visitors needed to learn both the good and bad aspects of wind energy, so we included a topic that discusses how wind machines affect the environment. *The Way it Works* includes two subsections, mechanical and electrical. In this area people will learn about the mechanical aspects of windmills and wind turbines, as well as how power is generated and transmitted throughout the power grid. To understand wind machines it is important to know how they work. The National Curriculum contains many topics about physics and electronics that covers such topics as rotation, forces, and circuits, all of which are important in explaining how wind machines operate. The fourth area is *Time Periods and Lifestyles*, which covers how wind machines affect the way people, have lived over the past two thousand years. This category fits into the history section of the National Curriculum, which contains topics about how people in different time periods lived and how technology affected their culture.

3 METHODOLOGY

The National Museum of Science and Industry is creating an Energy Gallery that will serve to educate its visitors about what energy is and how it affects their lives. Our team's contribution to this gallery is the wind energy component. For this project our team has proposed ideas for the design of both a physical exhibit and a virtual or web-based exhibit. Before designing the exhibits, our team used a questionnaire to determine the education level of the exhibit audience. After we performed an evaluation of the proposed exhibit ideas, we revised them to ensure that the designs effectively convey information about wind energy.

3.1 Physical Exhibits

The wind energy exhibits will contain both physical and virtual elements. The physical exhibit is the actual display in the museum. The science museum's Energy Gallery will include this display. These exhibits explain wind energy to museum visitors. They also investigate both positive and negative aspects of wind energy through the use of interactive learning techniques. In addition, these exhibits show how wind energy affects visitors' lives directly and how it has potential to be a major source of power for the future. Because many of the visitors to the Energy Gallery are in school groups, we incorporated as many of the National Curriculum topics as possible in these exhibits.

We utilised the National Curriculum for Key Stages two and three. We have administered questionnaires that have allowed us to gauge what visitors already know about wind energy. This questionnaire was designed for visitors of all ages because we asked people from each age group about their knowledge of wind energy. The results of the questionnaire have aided us in the development of both the physical and virtual exhibits. We also used this qualitative information to help us understand the information and concepts that need to be covered to achieve our goals of informing the visitors about the positive and negative aspects of wind energy while allowing them to experience "The Power of Wind."

Beyond looking at the general concepts of the exhibit we also ensured that the visitors were able to easily interact with it. We did this by looking at the science museum reports documenting mistakes and successes made in the past. It is also important to follow standard museum techniques such as having interactive and hands-on exhibits. Interactive displays are essential devices in keeping a person's attention. Our design proposals include a variety of interactive displays such as hands-on, computer based, or videodisc based activities. These interactive displays provide a means for visitors to comprehend better the material being presented because it forces the visitors to take an active role in the exhibits. We hope to engage the visitors in a variety of interactive displays to increase their knowledge of wind energy.

3.2 Virtual Exhibits

The virtual or web-based exhibit is an interactive experience for people who cannot visit the museum or supplementary material for people who can. These exhibits are a portion of the entire virtual energy gallery, which can be accessed through the museum's main web page. The virtual exhibits serve a similar purpose as the physical exhibits, and their main goal is explaining the positive and negative aspects of wind energy. We did this by using the same four main topics that we used to develop the physical exhibits. By breaking down wind energy into these sub-topics we hope that people will be able to relate to the concepts presented in the exhibit.

We used Human-Computer Interaction (HCI) techniques to design the virtual exhibits. These techniques provide a set of rules to follow when designing a web page to ensure that it is user friendly. There are eight golden rules of HCI. The first rule is "Consistency," which means that the format and style throughout the site must be the same from page to page. The second rule is "Reduction of Short-Term Memory Load," which states that the user should only have to remember between five and nine items at once. The third rule, "Reversal of Action," states that the user must be able to navigate the site quickly and easily. The fourth rule is "Internal Locus of Control," which means that the user must feel in control of the system and not feel as though he or she is being controlled by the system. The fifth is "Shortcuts," which allow the user to access another portion of the page quickly. The next rule is "Feedback," which says there must be an immediate response to the users actions. "Closure" is the seventh rule, and it means that the web site should have some finality to it. The final rule is "Error Handling," which states that the site should not crash if the user makes a mistake (Hilary, 1999).

Our team used *Bobby*, a web site analyser, which determines the accessibility of a web site to the disabled. This program especially helped us ensure that the colours, fonts, and images are suitable. We used this program to help us make our site accessible to a wider audience (Cast, 1999).

3.3 Evaluation

In order to ensure our exhibits are effective, we established criteria for them to fulfil. Next we evaluated our designs using the criteria to determine their success. We have defined exhibit success as an exhibit that is easy to use and understand, and one that effectively conveys the information and concepts that we have designed it to convey. Through the information that we gathered from our questionnaire and feedback.we obtained from our exhibit designs, we were able to create effective exhibits designs.

In creating and developing the display for the museum, our team had three goals in mind. The first of these goals was to make people think about wind energy. Fisher's research shows that many people feel they know all that they need to know about energy. Using what Fisher found, we hope to challenge this belief by showing many uses of wind energy and giving concrete examples of how it affects peoples' lives today and how it will continue affecting their lives in the future.

The second goal was to make visitors to the museum see how important wind energy is to them and people everywhere. Our exhibits show examples of how wind has been used over the past two thousand years to generate power. In addition to this, we hope to portray the many possibilities there are for using wind energy as a primary source of power in the future.

The third goal was to design a display that captures the attention of visitors long enough for them to fulfil the other two goals. We did this by designing a display that involves audiences of all ages and education levels. Interactive displays have proven to be the best way to capture a person's attention.

The next phase of our project involved evaluating and revising our exhibits. The evaluation of the physical exhibit was based on a series of discussion groups among various members of the museum staff. Illustrations and descriptions are the two methods we used to explain our ideas to the members of our discussion group. Following a presentation of our ideas, we asked questions to ascertain whether our ideas meat our three goals. Our first discussion group consisted of the energy team. After we tested our ideas and received feedback, we made revisions. We then tested our ideas by allowing other museum staff and visitors to interact with two of our exhibits. We then made our final revisions and submitted our ideas to the museum.

3.4 Conclusion

Our final report to the science museum contains the information we gathered from the questionnaires, our physical and virtual exhibit designs, and the evaluations and revisions made. We intend for the museum to utilise the physical exhibit ideas in the upcoming energy gallery. The virtual exhibit is to become part of the science museum's web site by this summer. It will act as a model for developing future energy gallery web exhibits.

4 DESIGN AND DEVELOPMENT

Several steps went into the design and development of our exhibit. We created a questionnaire and administered it to ascertain the visitors' knowledge of wind energy. This information assisted us with the design of the exhibits. We developed preliminary designs for the physical and virtual exhibits through the use of our questionnaire results and background research. The exhibits underwent an evaluation process to ensure their quality and effectiveness in explaining wind energy to the museum visitors. After each stage of pre-testing and testing, we analysed the results to improve our exhibit designs.

4.1 Establishing the Need

The National Museum of Science and Industry is in the process of designing a new gallery dedicated to conveying the importance of energy. This gallery will contain information about energy including specific information about how it has been used throughout history. Part of the Energy Gallery is the *Futures* section where the museum will present visitors with knowledge about future energy sources. Wind energy will be a component of this section. Therefore, we gathered information to design exhibits that show how wind machines have developed throughout the ages, how they are used in today's society, and how they may be used in the future.

The United Kingdom employs a nationwide mandatory curriculum, which every school must follow. The National Museum of Science and Industry includes topics from the National Curriculum to encourage school groups to visit the museum. Many topics in the National Curriculum deal with energy transformations, physics, and history. We included these topics in the wind energy section of the Energy Gallery.

This team conducted extensive research on windmills and wind turbines to determine the information that the exhibits should convey. We read many articles and books and visited a wind turbine to further our understanding of what wind energy is and how it has impacted society. We used the information gathered from our research to develop our exhibits.

In order to assess the knowledge of the exhibit audience, our team administered a questionnaire to the visitors. We did this to make sure that our exhibits were suitable for visitors with varying degrees of education. We used this information along with other surveys that the science museum had conducted to develop interesting, educational, and entertaining wind energy exhibits.

4.2 Questionnaire

The project team chose fifty museum visitors at random to participate in the questionnaire regarding wind energy. We distributed the results from this questionnaire to the Energy Team, which included all the people working on developing the Energy Gallery, to expand their understanding of the museum visitors' existing knowledge. Our team used these results for further development of the wind energy exhibits.

4.2.1 Pre-Test

We tested the questionnaire before using it as a tool for gaining information. The original questionnaire had twelve questions dealing with wind energy specifically and did not contain any questions about other forms of energy. Our team used an earlier questionnaire about energy conducted by Sophie Duncan and Claire Bonham-Carter as a model to develop our questions. We used a similar format and question structure as they did. The pre-testing had two phases to ensure that our final questionnaire would be effective in gathering the desired information.

The first round of testing took place with our liaison, Sophie Duncan, whose experience aided us in determining the effectiveness of our questions. Ms. Duncan reworded some of our questions and suggested that we add some introductory questions about energy and renewable energy sources. She also recommended that we use pictures of windmills and wind turbines to assist the visitors in answering our questions. Our team added the introductory questions about energy and renewable energy. We chose to use the pictures only for the younger children because we thought that young adults and adults would not need to see a picture of a windmill and a wind turbine to help them answer the questions.

The second round of testing involved asking six different museum visitors of varying ages to answer our questions. The revised questionnaire was administered to a male and female visitor in each main age category, which are children, young adults, and adults. The evaluation process allowed us to see that our questionnaire was too long and some of the questions were unclear. We also found that it would help visitors of all ages to see pictures of a windmill and a wind turbine. Given the results of the pre-testing, we removed some of our questions and reworded others so that the questions were more concise.

4.2.2 Final Questionnaire

The questionnaire, located in Appendix B, began with a question on energy in general. The remaining questions addressed renewable energy, wind energy, windmills, and wind turbines. More specifically, the questionnaire contained questions that asked the visitors' opinions about the use of wind energy.

The team administered the questionnaire to both male and female museum visitors of varying ages. We divided the age range of the visitors into three categories: eight to fifteen, sixteen to thirty-five, and over thirty-five. Each team member took responsibility for one category and questioned between fifteen and twenty visitors in that category. Each team member selected every third visitor who fit in his or her age category as the visitors walked by a particular area.

4.2.3 Results

We analysed the results of this questionnaire to determine any patterns that occurred. These results are located in Appendix B. This study found that eighty-four percent of museum visitors have a general understanding of wind energy, but they do not know the details. Some visitors know nothing about wind energy. The information that participants did possess varied widely. About one-fourth only knew that the windmills' and wind turbines' blades spun. Half of the visitors had a vague understanding of the purpose of these wind machines. Sixteen percent suggested that wind machines were used to generate electricity. Less than five percent mentioned anything about windmills being used to pump water, grind grain, or saw timber. When shown pictures of windmills and wind turbines, most visitors recognised what they were. The pictures aided the visitors in explaining how the machines worked.

Most participants said they knew what renewable energy was, but could not clearly define it. When asked to choose which countries use wind energy, most participants could only guess. Thirty-nine people thought that the main reason wind energy should be used more was because it was environmentally friendly. Half of the participants found the topic of wind energy interesting. About half of the participants described wind energy as a clean, renewable, and/or safe source of energy.

The raw data gathered from the questionnaire was extremely important in determining participants' knowledge. From these data, we were able to determine the average knowledge of the participants. The results from the questionnaire allowed us to design exhibits with an appropriate content level.

Some of the results from the questionnaire are different than we expected. Fifty percent of the participants found wind energy to be an interesting topic. This finding differs from the results of the Susie Fisher Group who found a lack of interest among visitors (Susie Fisher Group, Chart 6). We were also surprised to discover that most people do not know the different purposes of windmills.

4.2.4 Impact on Our Project

This information aided our team in developing exhibits that accurately explained wind energy. An understanding of what people already know helped us to design exhibits at an appropriate educational level. Without this questionnaire, we would have had to rely on information gathered by the Energy Team and the Susie Fisher Group, which is too broad because it only covers energy in general. This questionnaire helped us because it was specific to wind energy.

4.3 Design Criteria

It is necessary to establish the goal of each exhibit and to determine how the success of an exhibit will be measured before one starts testing exhibits. We have accomplished this by setting goals for the wind energy section of the Energy Gallery. We used the responses from the people who test our exhibits to further gauge its success.

Our goal is to educate museum visitors about wind energy. We would like them to understand both the negative and positive aspects of wind energy. We would also like visitors to learn about different types of wind machines and how each of them is used. It is also important for visitors to learn about the different types of wind machines throughout the world. We also think that the exhibits should be interactive and enjoyable.

We measured the success of our exhibit designs by testing them with our liaison, the Energy Team, other museum staff, and museum visitors. Through testing we were able to determine if the users understand the exhibit. From this information we also learned if visitors are able to extract new knowledge from our exhibits. The museum staff helped us correct common exhibit mistakes. Hearing museum staff and visitors talk about the exhibits after they had seen them also allowed us to see if they were learning new and interesting information.

4.4 Exhibits

After investigating the National Curriculum and analysing the questionnaire results, we were able to develop ideas for the physical and virtual exhibits. The exhibits provide the visiting audience with a well-rounded view of wind energy.

We developed our thirteen original ideas through brainstorming and using the knowledge that our background research provided, descriptions of which can be found in sections 4.5 through 4.17. We classified each design in three ways. The first classification is determining which of the four subsections of our content the exhibit falls under. These subsections are: *The Way it Works, Time Periods and Lifestyles, Climates and Countries,* and *Environmental Impacts.* Each subsection deals with a specific idea in regards to wind energy. The second is whether the exhibit is a physical exhibit, a virtual exhibit, or both. The last classification identifies the type of exhibit, either interactive or object-based. An outline containing the twelve original exhibits and definitions can be seen in Figure 7.

Each exhibit went through a series of testing phases. There were three possible testing phases for each exhibit. During the first phase, the team employed Sophie Duncan to review and comment on the exhibit ideas while they were still in the form of sketches and drawings. After reviewing them, she met with us to discuss her suggestions, and we explained anything that was not clear from our sketches. This testing phase allowed us to improve our exhibits, eliminate potential problems, and eliminate the concepts that would not work. Ms. Duncan's expertise helped in the next phase of testing by removing many of the major design flaws.

The second phase of testing employed the members of the Energy Team to participate in a discussion group, the results of which are displayed in Appendix C. The exhibit ideas that reached this phase were drawn on large poster boards and displayed for the Energy Team. These exhibits included the revisions after the first phase of testing.

The third and final phase of testing was conducted with visitors, museum staff, and WPI students, the results of which are located in Appendix D. The exhibits that were brought to phase three were modelled using HTML or Flash. Descriptions of how these exhibits were modelled are located in their respective exhibit description sections. The participants of this testing were allowed to use the models as if the models were on the web or on gallery.

The testing process was not the same for each exhibit. We brought only the *Where in the World* exhibit and the *Wind Power Matching Game* through three phases of testing. *Working Turbine, Wind Table,* and *Hearing the Wind* were brought to stage two. The rest of the exhibits were only tested during the first stage. Time and practicality issues involved in both testing and development were responsible for bringing the testing on some exhibits to an early stop. An example of these issues included the significant amount of time and money required to build mock-ups of the physical exhibits for testing purposes.

After the testing and revision process was complete, the exhibits that were not eliminated were labelled as final exhibits. Some of our original exhibit ideas are not part of our final exhibits because we determined that they would not be effective tools in conveying our message about wind energy. The exhibits that were labelled as final can be identified in the following sections by their subsection labelled "Final Design." A set of final exhibit template sheets is contained in Appendix F.

Exhibit Name	Content Topic				Location		Type	
	Time Periods and Life Styles	Climates and Countries	The Way it Works	Environmental Impacts	Web	Gallery	Interactive	Object Based
Inner Workings			X			X	X	
Working Turbine			X			X	X	
Pinwheel Creation Table			X		X		X	
Airfoil Lift Demonstration			X		X			X
Life Cycle				X	X	X		X
Wind Power Matching Game	X				X	X	X	
Timeline	X				X	X		X
Wind Table		X				X	X	
Where in the World		X			X	X	X	
Hearing the Wind				X		X	X	
Good Vs. Bad				X	X		X	
Power of Wind						X		X
Image Gallery					X			X

Figure 7 - Exhibit definition outline

4.5 Inner Workings

Inner Workings is an interactive physical exhibit in the form of a puzzle. It serves to explain how the inside of a wind turbine works. We set up four stations, and at each station the visitor is invited to add a new piece to the turbine puzzle. The first station allows the visitor to place the pole into the base. The next station allows the visitor to put two pieces inside the pod, which contains the generator, the nacelle, or generator covering, and the rotor. The visitor can then add the cap including the blades at the third station. At the final station the visitor can see the turbine spinning by pressing a button that releases air onto the turbine. Each station contains an explanation of the function of each component that the user assembles.

4.5.1 Testing Phase 1 – *Inner Workings*

Our team gave this exhibit to Ms. Duncan for review. She thought that this exhibit would be successful in explaining how a wind turbine works from the inside, but she suggested an alteration in the final station. Instead of allowing the visitor to press a button to see the turbine work, she thought it would be better if the visitor were able to construct the entire turbine at this point and then test it to see if it worked. If the visitor put the turbine together properly the turbine would work.

4.5.2 Final Design – *Inner Workings*

Our team thought that Ms. Duncan's suggestion would be beneficial in explaining how a turbine works. Therefore we have made this change to our final exhibit. This exhibit did not go through the second or third testing phase because we developed it at a later stage and therefore did not have time to test it further. Our final design for this exhibit includes four stations. The first allows the visitor to place the tower of the turbine. The second station calls for the visitor to place the generator and gearbox into the pod of the turbine. The third station allows the visitor to put the cap and blades onto the turbine. The final station is a combination of the other stations and allows the visitor to put the entire puzzle together and see if it works. The final station is enclosed by a glass case with a door, which acts as a safety device. The visitor is not allowed to activate the turbine without closing the door. A sketch of this exhibit is shown in Figure 8.

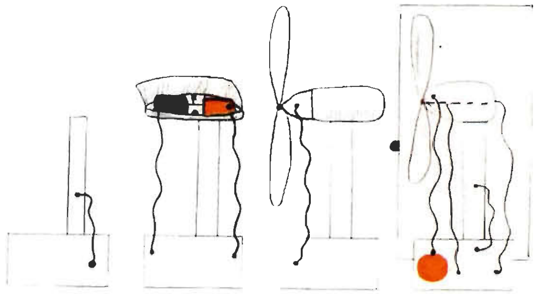

Figure 8 - *Inner Workings* sketch

4.6 Working Turbine

The *Working Turbine* exhibit falls into the category *The Way it Works*. It consists of a functioning wind turbine mounted inside a Plexiglas wind tunnel. The user of the exhibit would have the ability to control certain functions of the wind turbine such as the angle it faces into the wind, the feather angle of the blades, or the action of the propeller tip brakes. The user's actions would result in better or worse efficiency of the generator.

A visual feedback device, such as a light bulb or a toy train powered by the turbine, would demonstrate the current power output.

4.6.1 Testing Phase 1 – *Working Turbine*

Ms. Duncan reviewed this exhibit and did not note any problems with it. As a result, we did not make any changes before testing it with the Energy Team.

4.6.2 Testing Phase 2 – *Working Turbine*

During the discussion group, the Energy Team suggested putting multiple turbines in the wind tunnel instead of just one. Having more than one turbine in the wind tunnel would better justify the cost and floor space used. They recommended that the turbines should be of varying blade length, width, orientation, and number. This would allow visitors to interact with multiple types of turbines. Another idea that the energy team had was to use the airflow generated by the wind tunnel to power the *Wind Table* (see section 4.12).

4.6.3 Final Design – *Working Turbine*

We considered having multiple turbines for the *Working Turbine* exhibit, but we thought that it was best to have one. If more than one were present, it would be very complex to have a turbine pop up from the ground. Therefore our

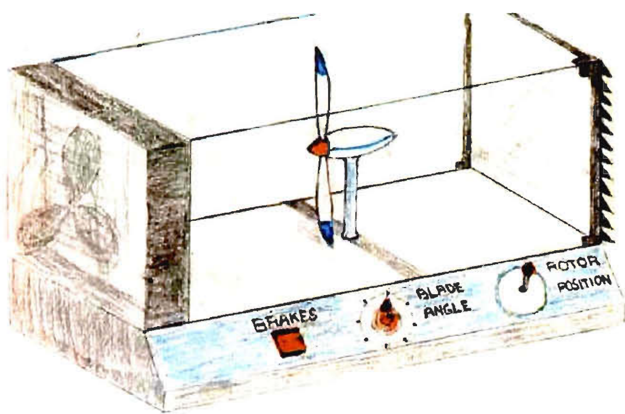

Figure 9 - *Working Turbine* sketch

final design consists of a single wind turbine enclosed in a wind tunnel. The visitors have the ability to control the direction of the turbine, the angle of the blades, and the action of the blade tip brakes. In addition, the exhaust of this exhibit could be used as the airflow for the *Wind Table* exhibit. We have provided a sketch of this exhibit in Figure 9.

4.7 Pinwheel Creation Table

The *Pinwheel Creation Table* helps to explain how windmills and wind turbines work, and therefore is also included in *The Way it Works* category as an interactive physical exhibit. Visitors are able to make their own pinwheels. Constructing and interacting with the pinwheels allows visitors to learn more about wind machines. They will also be able to take their pinwheels home with them.

4.7.1 Testing Phase 1 - *Pinwheel Creation Table*

The *Pinwheel Creation Table* would require the presence of a member of the museum staff at all times. Ms. Duncan said it would not be possible to have an exhibit in the gallery that required a staff member. Therefore, she said that the physical aspect of this exhibit would only be possible as a workshop. She thought that it would be a very successful workshop because it would let visitors physically realise how a wind machine works. It would also give them something tangible to take home.

4.7.2 Final Design - *Pinwheel Creation Table*

We eliminated this exhibit from our physical exhibit plans, but we did not completely abolish the idea. We propose that the museum provide a set of instructions for making a pinwheel on the web page. The virtual exhibit contains directions that people can print out and follow to create their own pinwheel. The exhibit also explains why a pinwheel works and how a pinwheel is similar to a wind machine. We believe these instructions would be especially beneficial to a teacher in a classroom environment.

We propose that the museum use these instructions in a future workshop. The visitors would receive instructions and assistance in making their pinwheels. They could then apply their understanding of how a pinwheel works to the way a windmill or wind turbine works.

4.8 Airfoil Lift Demonstration

The *Airfoil Lift Demonstration* exhibit would be both physical and virtual. Its purpose is to demonstrate how an airfoil produces lift specifically with respect to propeller-style airfoils. It is thus grouped into the category *The Way it Works*. The web version of the exhibit includes animations of a propeller spinning and arrows that show how the air flows around the propeller. The physical exhibit incorporates a freewheeling propeller inside a wind tunnel. Smoke streams flow over the spinning blades to demonstrate how the spinning propeller affects the air. This exhibit is not interactive and thus placed in the object-based category.

Through many debates we decided that we did not need the A*irfoil Lift Demonstration* as part of our physical exhibit because many of the same themes are covered in the *Working Turbine* and in Flight Lab, which is another section of the museum.

4.9 Life Cycle

The *Life Cycle* exhibit explains the life cycle of a wind turbine. This virtual exhibit will include a web camera of the wind turbine that the county of Norfolk is planning to build. This virtual exhibit will contain an explanation of the process of building a turbine including its cost.

The *Life Cycle* of a turbine exhibit is not a practical exhibit because the construction of this turbine will only take three days. We have suggested making a time-lapse video for visitors to download, which shows the existing wind turbine being built. We attempted to obtain a video from EcoTech, which runs the turbine located in Norfolk, but we were unable to do so.

4.10 Wind Power Matching Game

The *Wind Power Matching Game* falls under the *Time Periods and Lifestyles* category as an interactive physical and virtual exhibit. In the original version of the physical exhibit, the museum visitors are given the task of matching a given time period with its correct wind machine. Turning a three-sided figure accomplishes this. A correct answer results in a video clip displaying information about that wind machine and time period. The virtual exhibit is similar to the physical exhibit. The user has to accomplish the same task, but the correct answer displays an image with written text explaining that time period and wind machine.

4.10.1 Testing Phase 1 - *Wind Power Matching Game*

The first problem encountered with the physical version of the *Wind Power Matching Game* is that people would probably want to spin the pictures of this exhibit instead of actually trying to match them. Ms. Duncan also informed us that people might have trouble matching different time periods. To make the outcome more interesting, Ms. Duncan suggested that the pictures be animated.

4.10.2 Testing Phase 2 - *Wind Power Matching Game*

The energy team suggested some improvements to the *Wind Power Matching Game* exhibit. One person said that we should include a centre block that shows what the windmill was used for. They commented that it would also be beneficial to include how the same wind machine was used in different countries for different applications. The energy team emphasised the importance of testing this exhibit with museum visitors to make sure that it is possible for them to match wind machines with different time periods.

4.10.3 Testing Phase 3 – *Wind Power Matching Game*

For the third phase of testing, we constructed a virtual mock-up of the *Wind Power Matching Game*. This mock-up served as a test platform for the physical exhibit, a test platform for the virtual exhibit, and a starting point for the final virtual exhibit that we submitted to the Energy Team for publication on the World Wide Web. We created this mock-up using Macromedia Flash 4.0. We designed the exhibit to incorporate the three digital images of wind machines and three corresponding images of their respective time periods that we intended to use in the final physical exhibit. However, the team experienced difficulties locating and acquiring royalty-free photography to represent the time periods. In response to this, we decided to change the theme of the time period images to images that portrayed the products of the respective wind machines. These images were not only easier to find, or create, but they also maintained the *Time Periods* *and Lifestyles* theme by showing how the wind machine benefited the society that implemented it.

The three wind machines that the team chose to use were the German Enercon – E66 wind turbine, an English 18th century post mill, and an American 19th century wind pump. The image that represented the product of the Enercon – E66 was an image of electric pylons; the representative image used for the post mill was grain; and the image used for the wind pump was an image of a pump extracting water from underground.

We tested the *Wind Power Matching Game* virtual mock-up on six members of the museum staff, thirteen museum visitors on gallery, and five WPI students at their flats in London. The results from this testing, found in Appendix D, were extremely helpful in improving our exhibits. During testing of this exhibit, twenty out of twenty-four of the participants said that they found it interesting. Our observations revealed that nineteen out of twenty-four visitors began by reading the instructions. When asked about the message of the exhibit, the most common response was that it served to teach people about the different types of wind machines. Some of the visitors encountered difficulties in identifying some of the pictures. The pictures of the water pump and the grain caused the most problems. When asked to rate the exhibit on a scale of one to five, one being uninteresting, and five being very interesting, the average of all responses was 3.6.

4.10.4 Final Design - *Wind Power Matching Game*

For the physical exhibit, our team recommended that the moveable parts of the time period matching game contain some component of friction thus making it difficult for a person to spin them rapidly. From our discussion with Ms. Duncan, we decided to choose each of the three sets of pictures in the *Wind Power Matching Game* from a distinct time period. To make the exhibit more interesting to observe, a monitor accompanies the physical exhibit instead of having animated pictures. For

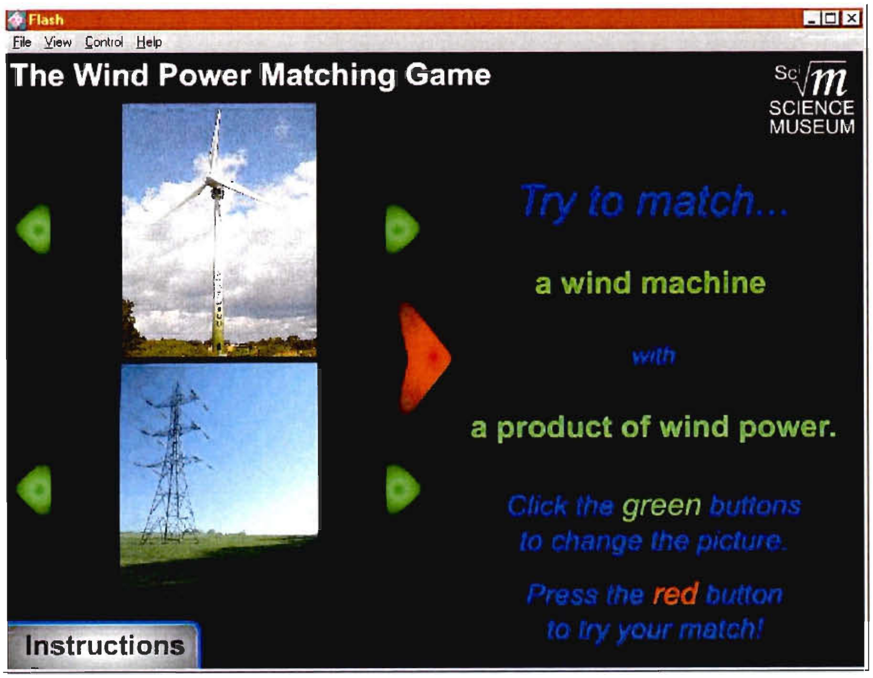

Figure 10 - *Wind Power Matching Game* Flash mock-up

the virtual exhibit, when a match is made the visitor is able to see a picture and a description of that wind machine. We decided not to have a centre block, as was suggested, displaying what the wind machine produces. Instead, the video clip will cover this information. The video clips will be from different countries, which will satisfy the design criteria of applications in different countries. A narrated slide show could replace the video clips if cost was a problem or if the video clips were not available.

We extracted several specific pieces of data from the third phase of testing that would specifically improve the virtual version of this exhibit. We found that most participants during testing read the instructions carefully. However, when we talked to museum staff we found that visitors read instructions when they are testing an exhibit, but they are less likely to read the instructions when they are in the museum. Because the instructions are so important to successful operation of the game, we changed them from a block of white text at the bottom of the screen to an attractive, multicoloured, and much larger series of phrases that better conveyed the meaning and instructions of the exhibit. In addition, the button that activated the match was changed from green to red to distinguish it from the buttons that control which image is displayed. After a match is attempted, the game waits for the user to change an image again and immediately returns the output screen back to the instructions. We also changed the correct-answer output movie to include a message informing the user that he or she had made a correct match. Figure 10 depicts a screenshot of the flash mock-up. Finally, we found that the visitors had trouble distinguishing some of the pictures that are part of this exhibit. We suggest that the museum find new images to replace the grain picture, the ground water pump picture, and the correct match pictures for the water pump and windmill.

Our team believes this exhibit qualifies as successful and would be beneficial as an exhibit. The visitors and staff that tested the virtual mock-up were able to identify its message in almost every instance. They also gave it an average rating of 3.6 on a scale of one to five, which shows that they are more interested than disinterested in this exhibit. This shows that the exhibit contains a component of both education and enjoyment, which is what we hoped to achieve.

4.11 Timeline

The *Timeline* fell under the *Time Periods and Lifestyles* category and could be implemented as either a physical or virtual interactive exhibit. The physical exhibit was a display illustrating the evolution of wind machines. The virtual exhibit allowed the user to click on a time period to produce information about the types of wind machines used during that time and what they were used for.

We decided that the *Timeline* would not be a successful part of the Energy Gallery because it would contain too much text for the visitors to read. Another reason for our decision was that the history of windmills does not easily fit into a timeline because the use and evolution of different mills varied depending on the geographical location.

4.12 Wind Table

The *Wind Table* is a physical exhibit in *The Way it Works* category. The purpose of this interactive exhibit is to explain the importance of placement and direction of a wind machine in terms of its output. The *Wind Table* contains a mountainous area, fields, water, and a shoreline. This diverse topography allows the visitors to see how geography can affect the efficiency of wind turbines. Visitors are able to place the turbines into sockets on the model. After placing the turbines and rotating them to face the desired direction, visitors press a button to start the airflow. At this point the blades on the turbines spin, a kilowatt monitor displays a measure of the power that would be generated if it were a real wind farm, and a light bulb lights up. The exhibit keeps score of how much energy is produced by the visitor's arrangement of wind turbines. If the visitor surpasses the high score the new score is recorded. We felt that allowing the visitors to try to beat the high score would encourage them to try to find the best locations to place the wind turbines.

4.12.1 Testing Phase 1 - *Wind Table*

Ms. Duncan thought the *Wind Table* exhibit would be successful but there were some problems to address. One such problem was having rotating blades because it would be easy for children to injure themselves. Because the wind turbines are not attached to the table, a person could easily walk away with one of the turbine models, which becomes a concern when considering the cost of replacement. Ms. Duncan suggested that we design the table to contain a grid that would allow the visitor to slide the turbine to the desired location, solving this problem. One of the qualities that she found attractive was the ability of the visitor to interact physically with the exhibit.

4.12.2 Testing Phase 2 - *Wind Table*

The Energy Team thought the *Wind Table* would be successful in educating the visitors about the placement of turbines. Our team suggested two ideas regarding the use of air across the table. The first was having a constant flow of air across the table, and the second was having a button that could be pressed to activate the wind. The energy team thought that a constant flow of air would be more appropriate because it would allow many people to participate at once. Having the wind produced by a button would inhibit group activity because only one person could control the flow of air.

Another problem that was discussed was the theft of the turbines. The energy team thought the idea of having a grid on which one could slide the turbines could be problematic because it would be more time consuming and complicated especially for smaller children. They gave an alternate suggestion of having the turbines attached to chains, but this would most likely result in the chains becoming tangled. Pushing buttons to activate different turbines would eliminate the possibility of having the visitors change the angle of the turbine. The Energy Team suggested that we create another exhibit dedicated to efficiency depending on angle instead of combining it with the placement of turbines in this exhibit. Separating these two concepts would make the exhibit easier to understand for younger visitors.

4.12.3 Final Design - *Wind Table*

Taking these suggestions into consideration, we proposed that the turbines be made out of a material that is flexible to prevent injury when the blades are turning. We considered having a button that would turn on the flow of air, but we thought this would eliminate the group aspect of this activity because it would leave one person in control. Therefore we decided to have a constant flow of air across the table, which should not be harmful since the turbines will be flexible.

The main concern regarding the *Wind Table* involved the moveable turbines. Our team thought the best way to combat this problem was to have pop-up turbines. The visitor would be able to press a button to produce a turbine in a given location. Visitors are not able to make more than ten turbines show at a time. When visitors make changes to the turbine positioning a kilowatt monitor, light bulb, and high score board will record the changes. We decided to make this exhibit focus only on placement and left the concept of the most effective direction to face a wind turbine to the *Working Turbine*. Figure 11 depicts a sketch of the *Wind Table*.

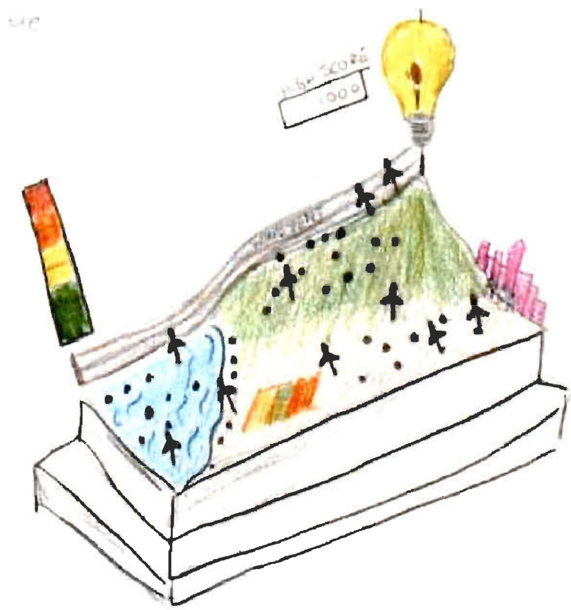

Figure 11 - *Wind Table* sketch

4.13 Where in the World

Where in the World falls under the *Climates and Countries* category as an interactive physical exhibit. This exhibit consists of a globe three feet in diameter standing on a base that is two feet high. It has buttons marking the locations of wind turbines. The visitor can press the button in the country containing the desired wind farm. A video monitor on the globe then displays a video clip of this particular wind farm.

4.13.1 Testing Phase 1 – *Where in the world*

Ms. Duncan suggested that we have many smaller globes instead of just one large globe. These globes would hang from the ceiling with an arrow pointing to the area on the globe where there is a wind farm. A chain would hang down that visitors could pull to hear about that wind farm. Ms. Duncan thought that this would allow more visitors to interact with the exhibit at one time.

4.13.2 Testing Phase 2 – *Where in the world*

The Energy Team had some concerns regarding the *Where in the World* exhibit. One concern was the use of videos because they are expensive to make and difficult to find. The size of the globe would inhibit small children and disabled visitors from reaching the top. The Energy Team suggested that a secondary set of buttons be placed below each monitor to allow for easier access. They also informed us that the science museum did not use buttons that were smaller than 30 mm in diameter or 45 mm by 20 mm square. This would prevent us from putting multiple buttons in small countries.

They also suggested displaying the power output of each location in kilowatts and in number of houses powered.

4.13.3 Testing Phase 3 – *Where in the World*

Our team tested the *Where in the World* exhibit using a combination of museum visitors and WPI students. We developed a mock-up in HTML that we could use to test both the physical and virtual components. The virtual exhibit contains a picture of a large world map with buttons in the location of wind farms. There is also a navigation bar at the bottom for those who want to choose the wind farm based on the country's name. Clicking on a particular button or country brings the user to a screen containing pictures and facts about the selected wind farm. We used Fireworks to design the image map for the web page.

4.13.4 Final Design - *Where in the World*

In following Ms. Duncan's desire to have more visitors interact with the exhibit at one time, we decided to have three monitors on the globe. We thought having one large globe would be more likely to attract visitors, and therefore we decided to stay with this plan as opposed to having multiple globes. The globe will be large enough to contain enough buttons and monitors to accommodate more than one visitor at a time. Figure 12 shows a sketch of the globe.

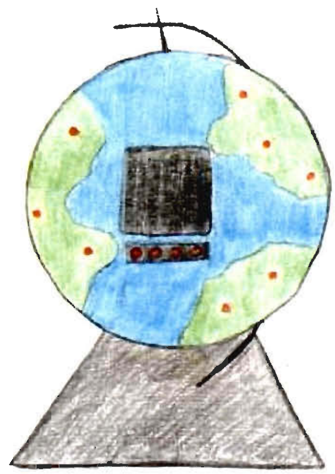

Figure 12 - *Where in the World* sketch

One of the concerns for the *Where in the World* exhibit was the cost of video clips. We proposed an alternate plan of using slides instead of a video if the expense is too great. We also have a panel beneath the monitor to accommodate disabled visitors and children who cannot reach all the buttons. Finally, we designed this exhibit to allow for proper sized buttons.

During the third testing phase we discovered that many visitors had difficulty navigating the site. Many asked how to get from the individual country pages back to the image map. Thus, we added a back button to allow the visitor to go back and forth with ease. We also noticed that the visitors found the text to be too wordy and dense. Rarely did any visitor read all of the text. We solved this problem by breaking up the text and using bullets to explain the important facts. Many people suggested having more pictures in this site. We are suggesting that the museum obtain pictures of turbines that they can add to the web site. A screenshot of the web page can be seen in Figure 13.

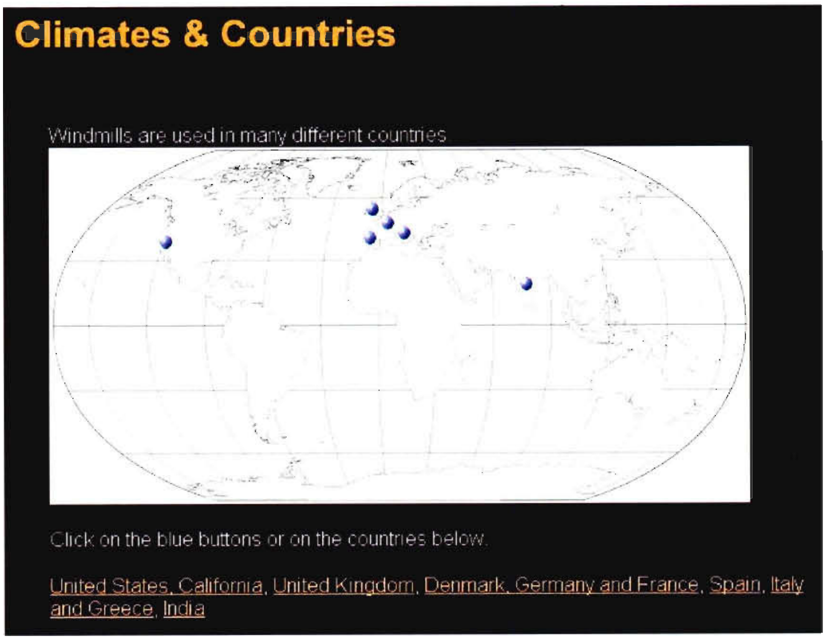

Figure 13 - *Where in the World* web exhibit

4.14 Hearing the Wind

Hearing the Wind is an interactive physical exhibit that will contain three different stations of varying heights that will play wind sounds. The visitor will step into a booth and press buttons to hear different wind machines as well as common sounds for comparison. An image will show the visitor a picture of the source of the sound.

4.14.1 Testing Phase 1 - *Hearing the Wind*

Ms. Duncan also liked *Hearing the Wind* because it allowed people to experience what it would be like to stand next to a wind turbine. She was enthusiastic about the idea of having a visual picture with the sound affect because it would entice visitors to use the system longer. She believed we should choose sounds that many visitors recognised so they can truly understand how loud or quiet a wind turbine is. One of the most popular misconceptions of wind turbines is that they are very loud. We hope to change this by showing that they are actually quieter than many common sounds. Some ideas that we have for sounds are traffic, a baby crying, a hairdryer, and wind blowing through bushes. We also decided it would be beneficial to make three stations of varying heights for this exhibit to accommodate all ages and those with disabilities.

4.14.2 Testing Phase 2 - *Hearing the Wind*

The Energy Team proposed some alternate ideas relating to the *Hearing the Wind* exhibit. They thought it would be interesting to have a survey component to the exhibit that would allow the visitor to choose the most irritating sound. Another suggestion they made was to have a rocker switch that would switch between a wind turbine and another sound. This would allow the visitor to compare each sound with the turbine. The Energy Team was helpful in directing us to the National Sound Archive where we could borrow sounds for the development of our design.

4.14.3 Final Design - Hearing the Wind

Our team thought it would be best to have seven buttons in total for the *Hearing the Wind* exhibit. There would be three large buttons containing the sound of a windmill, wind turbine, and wind farm. The remaining four, smaller buttons will be traffic, a baby crying, a hairdryer, and wind through a bush. Figure 14 shows a sketch of the sound station with its headphones to the left.

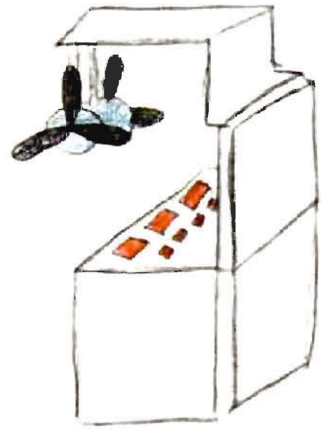

Figure 14 - *Hearing the Wind* sketch

We used Flash to design a virtual mock up of this exhibit. There were buttons for each sound and a survey for the user to choose which sound is most annoying. We were not able to obtain sounds from the National Sound Archives without purchasing them, and were therefore not able to add sounds into this site. This prevented us from undergoing a third phase of testing. We submitted this virtual exhibit, seen in Figure 15, to the science museum for their use once they obtain sounds.

Figure 15 - *Hearing the Wind* Flash mock-up

4.15 Good Vs. Bad

The *Good Vs. Bad* virtual exhibit serves the purpose of demonstrating the problems and benefits with using wind energy. This exhibit deals with a variety of environmental concerns, which is why it is part of the *Environmental Impacts* category. In this game, the user is allowed to build turbines wherever he or she wants in the city. The person will encounter various problems along the way. Some of these problems are unhappy residents, insufficient wind, and a lack of money. The person must effectively place the wind turbines to keep people happy. If he or she is successful, the player wins the game.

4.15.1 Testing Phase 1 - *Good Vs. Bad*

The preliminary testing of *Good Vs. Bad* did not reveal the problems that it would create. Ms. Duncan thought that it was a good idea, and we initially thought it would provide an excellent means of conveying information. Once we began investigating how we would create this exhibit, we realised that the amount of computer knowledge and time it would take to create and test it was not available to us.

4.15.2 Final Design - *Good Vs. Bad*

Although our team was not able to develop this exhibit further, we submitted the idea to the museum. *Good Vs Bad* is an interactive virtual exhibit game that will encourage visitors to create a working wind-powered world. Visitors would place wind turbines throughout a populated land trying to generate enough electricity for the people that live there. If the visitor does not please the people they will complain. Topics that they complain about will include aesthetics, pollution, killing of birds, building of roads, cost, and the destruction of trees and houses. From this game the visitor will learn about how wind machines affect the environment in which they are placed.

4.16 Power of Wind

The *Power of Wind* entranceway does not fall into one of the four content categories because it serves to attract the visitor to the entire site and therefore does not serve to display message. This exhibit will consist of a wind turbine and windmill on opposite sides with a banner between reading 'Power of Wind.' A light breeze will blow through the entranceway to give an indication of the content of the following exhibits.

4.16.1 Testing Phase 1 - *Power of Wind*

Ms. Duncan thought the *Power of Wind* entranceway would encourage visitors to enter the wind energy portion of the Energy Gallery. It would also allow visitors to see a model of a windmill and wind turbine. She did not see any problems with this exhibit idea.

4.16.2 Final Design - *Power of Wind*

The *Entrance Way* is an attractor. Our team did not make any changes to our original idea because Ms. Duncan did not see any problems with it. Therefore our initial description has been submitted to the museum for their use in the Energy Gallery. A sketch of the entranceway is displayed in Figure 16.

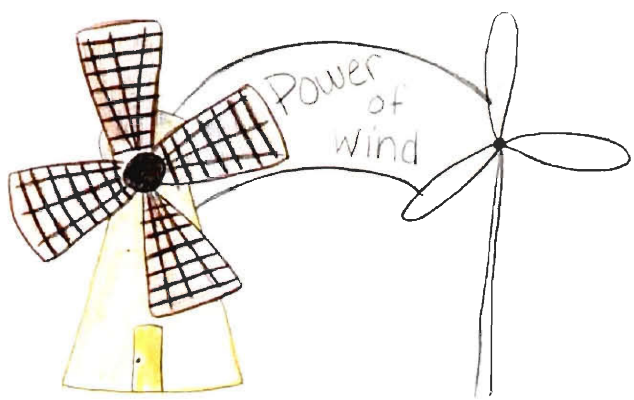

Figure 16 - *Power of Wind* sketch

4.17 Image Gallery

The *Image Gallery* is an object-based virtual exhibit. This exhibit contains a collection of photographs that are used throughout the rest of the virtual exhibit. This part of the virtual exhibit will provide visitors with easy access to pictures of windmills, wind turbines, and wind farms so that they can get a better understanding of wind machines. Since there were not enough royalty-free pictures available, we submitted this idea to the museum as an exhibit that they can add later.

4.18 Virtual Exhibit

The virtual exhibit includes all the content topic sections *The Way it Works*, *Time Periods and Lifestyles*, *Climates and Countries*, and *Environmental Impacts*. For each of these topics there is a web page. Each of these pages will include information about wind machines that is relevant to the particular section. A screenshot of the introductory page is visible in Figure 17.

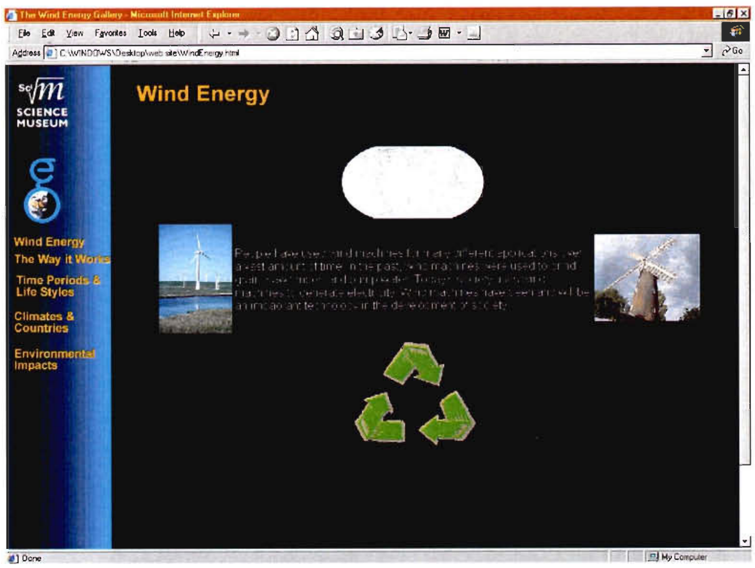

Figure 17 – Wind Energy Virtual Exhibit Main Page

The web pages follow a similar theme as the physical exhibits. We did this to keep consistency between the sets of exhibits. The virtual exhibit has a black background, orange text, and a navigation bar down the left side of the screen. A main wind energy page connects the four content pages. This page contains links to the other wind energy pages and to the main energy web page.

The Way it Works section of the web page contains links to pages that explain the mechanics of how windmills and wind turbines work. It also has a section on the aerodynamics that makes the blades on a wind machine turn. There is also a page that defines the watt; this page explains the difference between a watt, a kilowatt, a megawatt, and a terawatt.

Time Periods and Lifestyles includes information about how wind machines have been used throughout time. There is also a link to the *Wind Power Matching Game*, so visitors can play the game on the Internet.

The *Climates and Countries* web page includes information about where wind machines have been used throughout the world. This page includes the *Where in the World* exhibit, which links to different countries.

The last page contains information about *Environmental Impacts*. This page has information about the positive and negative impacts wind machines have on the environment.

This exhibit is meant to provide visitors to the website with a complete view of wind energy. Because we had trouble finding royalty-free images to use on our virtual exhibit we recommend that all of the repeated pictures be replaced with new images.

Through our three stages of testing we have developed nine final exhibits that will effectively explain wind energy to the public. The final exhibits cover all four content topic areas, both physical and virtual exhibits, and interactive and object-based exhibits.

5 CONCLUSION

Our team investigated the information our exhibit must communicate in order to be beneficial to the museum visitors. We engaged in an evaluation process to improve our designs. Multiple stages of evaluations and revisions led us to the development of exhibits that will be effective in the gallery. We proposed a series of exhibit ideas to be used in the Energy Gallery and we developed a web site pertaining to wind energy that can be accessed through the museum's main web page.

We used a variety of techniques to help us recognise the public's needs in terms of exhibit designs. These techniques included a questionnaire, a discussion group, observations, and informal interviews. The information that we gathered made it possible for us to design and develop our exhibit ideas for the Energy Gallery. Through each stage of testing we were able to make our exhibit ideas stronger. From our twelve original ideas, we selected nine of them to submit to the museum as final exhibits. We feel that these nine exhibits will effectively convey the important messages and topics to the viewing public. A table of these exhibits, seen in Figure 18, outlines the exhibit types and shows how far testing went with each exhibit. We hope that when museum visitors come to the wind energy section of the Energy Gallery they will walk away with a new understanding about how wind energy affects them and their environment.

Final Exhibit Name	Content Topic				Location		Type		
	Time Periods and Life Styles	Climates and Countries	The Way it Works	Environmental Impacts	Web	Gallery	Ineractive	Object Based	Testing Phase Completed To
Inner Workings			X			X	X		1st
Working Turbine			X			X	X		2nd
Pinwheel Creation Table			X		X		X		1st
Wind Power Matching Game	X				X	X	X		3rd
Wind Table		X				X	X		2nd
Where in the World		X			X	X	X		3rd
Hearing the Wind				X		X	X		2nd
Good Vs. Bad				X	X		X		1st
Power of Wind						X		X	1st

Figure 18 - Final exhibit outline

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APPENDIX A – National Museum of Science and Industry Mission Statement

The Museum exists to promote the public's understanding of the history and contemporary practice of science, medicine, technology, and industry. Education Implicit in the NMSI's mission is the use of the collections for a variety of educational purposes, for specialist scholars, particular educational groups, and the general public. This use of the collections is extended and complemented by interactive exhibits and programmes that bring visitors in different way into contact with the issues, processes and content of science, medicine, technology and industry.

The core objective relating to this is to interpret the collections and engage the public in the contemporary issues of science, medicine, technology, and industry.

In order to engage with the visitor we seek to place the visitor, or learner, at the centre of the process and emphasize first-hand rather than mediated experience, active discovery rather than passive instruction, and the development of understanding in context rather then the abstract comprehension of scientific ideas. These principles build on the particular strengths of the NMSI, which lie in its collections and exhibitions, its long-standing expertise in interactive or 'hands-on' techniques, and its expertise in informal interpretation in the galleries through, for example, explainers, actors, and warder-guides.

The approach is one that seeks to inspire the visitor and to create memorable environments and experiences that open people's minds to new ideas, new perspectives, and questions. The objective is to stimulate discussion and through, during the visit and subsequently, from which learning takes place.

The NMSI takes its place as a key institution for informal education. It provides means for visitors to develop the scientific and technological understanding that is a part of our contemporary culture so that they can participate more effectively in modern society, as voters, decision-makers, private consumers of science and technology, and as employees.

APPENDIX B – Questionnaire Report

Energy Gallery
Wind Energy Exhibit
Visitor Questionnaire Results

January 2000

TABLE OF CONTENTS

1 INTRODUCTION

This report is based on fifty individual interviews conducted with visitors to the National Museum of Science and Industry. The interviews took place 24 January through 26 January 2000. Laura Domey, Wendy Kogel, and Benjamin Newton performed the interviews.

We conducted the interviews using a short questionnaire seen on page seventy-two. We designed the questions to determine what visitors know about wind energy. We asked visitors about renewable energy, windmills, wind turbines, and the locations that wind machines. Sophie Duncan helped with the development of the questionnaire. We also pre-tested with six museum visitors.

We selected every third visitor to a particular exhibit to be part of our questionnaire, while trying to ensure an even representation of all age groups and both genders. Laura Domey interviewed children between the age of eight and fifteen. Wendy Kogel interviewed young adults between the age of sixteen and thirty-five. Benjamin Newton interviewed visitors above the age of thirty-six. Figure B-1 depicts the distribution of age and gender of our participants.

This report organises the raw data collected from the questionnaire. This data should be used for qualitative analysis only.

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Male	5	4	3	7	4	5	28
Female	4	3	5	6	3	1	22
Total	9	7	8	13	7	6	50

Figure B-1 - Distribution of Questionnaire Participants

2 SUMMARY

This study found that the majority of museum visitors have a general understanding of wind energy, but they do not know the details. However, there were some visitors who did not know anything about wind energy. The information that participants did know varied widely. Some only knew that the windmills' and wind turbines' blades spun. Others had a vague understanding of the purpose of these wind machines. Some suggested that wind machines were used to generate electricity. Only a few people mentioned anything about windmills being used to pump water, grind grain, or saw timber. When shown pictures of windmills and wind turbines most visitors recognised what they were. The pictures aided the visitors in explaining how the machines worked.

Most people said they knew what renewable energy was, but when asked to define it they had some trouble. When asked to choose which countries use wind energy most participants just guessed. Thirty-nine people thought that the main reason wind energy should be used more was because it was environmentally friendly. Half of the participants found the topic of wind energy interesting. Fifty-four percent described wind energy as a clean source of energy; fifty-two percent described it as renewable; and fifty percent described it as safe.

3 WIND ENERGY QUESTIONNAIRE

Hello, my name is ___ and I am working on a new gallery on wind energy, which is due to open in 2001 as part of the energy gallery. We are doing some research into what our museum visitors think about the subject. Would you mind answering some questions – it will not take more than 5 minutes. There are no right or wrong answers; we are interested in everything you have to say so if you are not sure have a guess.

1. Can you name some sources of energy?
2. Can you describe to me what renewable energy is?
3. How would you describe wind energy?
4. What are some of the ways of gathering wind energy?
5. How would you describe a windmill?
6. How would you describe a wind turbine?
7. Describe how windmills and wind turbines affect their surroundings?
8. How is electric power gathered from the wind?
9. Throughout the world do you think that wind energy is used a lot? Can you tell me which of these countries you think use wind energy?

America	Egypt	France	Great Britain
Holland	India	Italy	South Africa

10. Do you think wind power should be used more or less? Why?
11. Which of these words would you use to describe wind power?

Clean	Cheap	Expensive
Ugly	Noisy	Polluting
Beautiful	Dangerous	Safe
Renewable	Old	Interesting

12. Which of the following age categories do you fit into?

<8 8-12 13-15 16-18 19-35 36-50 >50 male/female

4 RESULTS BY QUESTION:

4.1 Question 1 - Can you name some sources of energy?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	>50	Total
Sun/Solar[1]	4	4	5	4	4	4	25
Waves/Water/Hydro/Sea[1]		2	4	8	5	4	23
Wind[1]		3	3	6	2	4	18
Gas[1]		3	1	6	2	2	14
Nuclear[1]		1	4	4	3	1	13
Coal[1]			2	2	3	3	10
Oil[1]			1	2	2	5	10
Electric[2]			2	2	2	2	8
Fossils[1]	1		2	3			6
Atomic[1]				2	1	1	4
Fuels[1]		2			1	1	4
Heat[3]		1	1		1	1	4
Chemical Energy[2]		1		2			3
Kinetic[2]		1	2				3
Light[3]	1				1	1	3
Movement[2]		1	1	1			3
Compression[2]	2						2
Everything[4]				2			2
Mechanic[2]			1	1			2
Petrol[1]	1			1			2
Balanced Forces[3]	1						1
Energy[4]		1					1
Fire[2]		1					1
Food[1]				1			1
Force[2]	1						1
Gravity[2]	1						1
Man Power[4]					1		1
Potential[2]		1					1
Springs[2]	1						1
Trees[1]	1						1
Us[3]		1					1
Wood[1]					1		1
Geothermal[2]			1				1
Power Stations[4]			1				1
Sound[3]	1						1

Question 1 cont.

Trends

- [1]**Sources/Fuels (87)**
  - Fifty percent of the responses were allocated to this category. Sun/Solar, Waves/Water/Hydro/Sea, Wind, Fossil, Atomic, Fuels, Petrol, Food, Trees, Wood
- [2]**Physical Definitions (27)**
  - 15% of the responses were physical definitions with electrical being the most popular. The other responses are Geothermal, Springs, Potential, Gravity, Force, Fire, Mechanic, Movement, Kinetic, and Chemical Energy.
- [3]**Physical manifestations (10)**
  - Heat was the most popular physical manifestation. The others were Sound, Balanced Forces, Light, and Us.
- [4]**Other(5)**
  - Other responses that did not fit into a category were: Power Stations, Man Power, Energy, Everything

4.2 Question 2 - Have you ever heard of renewable energy? Can you tell me what you know about it?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	>50	Total
Yes	5	7	6	7	4	5	34
No	4	0	1	6	3	1	15

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	>50	Total
Used Again & Again, More then once, Use over	2	6	2	4		2	16
All Energy is Renewable		1			1		2
Form that you can renew	1		1				2
Recycled	1	1					2
3 Kinds of renewable energy (non, partial & totally)				1			1
All Natural				1			1
Can not get rid of			1				1
Energy that you can always use				1			1
Get more of it	1						1
Not Limited			1				1
Sustainable Energy Source			1				1

Trends

The majority of people we talked to (about seven out of ten) said that they did know what renewable energy was. When asked to define it, only sixteen people (about one-third) could give a response. The definitions given followed the form of: renewable energy is energy that could be "used again and again," "used over," and "used more than once." The other two-thirds of the participants either have a partial understanding or have no understanding of the definition of renewable energy. The concept of renewable energy is important to the energy gallery so this information is very relevant to us.

Question 2 cont.

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	>50	Total
Wind			2	3	2	3	10
Water/Waves			2	4	1	2	9
Sun				1	1	1	3
Horse Dung					1	1	2
When Used it is not gone				1		1	2
Paper					1	1	2
Trees/Forests			1			1	2
Wind Turbines			2				2
Wood				1	1		2
Atomic					1		1
Biomass						1	1
Burn waste materials to create steam			1				1
Chlorophyll						1	1
Cycle						1	1
Food		1					1
Garbage						1	1
Gas			1				1
Not Fossil Fuels			1				1
Nuclear				1			1
Oil			1				1
Storage Heater					1		1
Used in Desert					1		1

Trends

When telling our team what they knew about renewable energy, many people gave examples of renewable energy sources. The most common source that visitors mentioned was wind with 21% of the responses. The second most common response was water and waves. All the other responses had less than one third the response rate compared to wind and water.

4.3 Questions 3 & 4 - How would you describe wind energy? What are some of the ways of gathering wind energy?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
A wind motion blowing that turns the blades of windmills and turns turbines to create electricity /Turns wind into electricity or power/ Makes electric power[1]	3	1	3	3	1		11
It spins around/Use wind to create /Wind blows and windmill turns[2]	3	1		2			6
Use a windmill/turbine that turns to generate electricity/ Cycles around to make electricity[1]		2	1	2	1		6
Energy/Produces Energy[1]	1	1				1	3
Harness wind for energy/Harnessing wind energy to make motor work /Energy produced from wind[1]				1	1	1	3
Energy that moves from air/Blows[2]		1		1			2
Fans turn generators & turbines[4]			1		1		2
High to Low Pressure[3]					1	1	2
Use wind energy to put into windmills[4]				1		1	2
Damaging to Environment[5]					1		1
Dynamo[1]			1				1
Environmentally Friendly[6]						1	1
Free[6]						1	1
Generators[1]				1			1
It can move it without touching it[4]	1						1
It is in the air[4]	1						1
Kinetic energy[3]				1			1
Natural[6]						1	1
Open Field[3]				1			1
Ugly[5]					1		1
Variable[4]						1	1
Velocity spins windmill drives water[3]						1	1
Wind Power[3]		1					1
							51

Questions 3 & 4 continued

Trends

- [1]**Energy/Electric Power (25):**
    - 49% of the responses for this question dealt with electricity or energy in some form or another. Makes electric power, cycles around to make electricity, produces energy, or energy produced from wind.
- [2]**Spins and Blows (8):**
    - 15% mentioned how the wind blows or the wind mills spins around.
- [3]**Facts (6):**
    - Mentioned random facts about wind energy. Wind power, Velocity spins windmill drives water, open field, kinetic energy, and high to low pressure.
- [4]**Questionable Answers (7):**
    - Some answers from participants were not quite right or they do not make any sense. “Variable,” “it is in the air,” “fans turn generators and turbines,” and “use energy to put into windmills.”
- [5]**Negative Responses (2):**
    - Two people had negative responses to this question saying that wind energy is damaging to the environment and ugly.
- [6]**Positive Responses (3):**
    - Three people had positive responses saying that it is natural, environmentally friendly, and free.

Question 3 & 4 cont.

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Windmills	2	2	3	6	4	4	21
Wind Turbines/Wind Turbo			2	2	2	1	7
Sails					4		4
Wind Tunnel		1	3				4
Waves					1		1
Wind Machine						1	1

No Answer for question #3	2	2	1	2	1		8
No Answer for question #4	7	5		6	2		20

Trends

Approximately 50% of the respondents that mentioned a source of wind energy mentioned windmills. Only seven said wind turbines, which we thought was surprising because when we showed them the picture later, most participants knew what it was.

In general, the participants thought that wind energy related to turning wind into electricity. The most commonly named form of a wind energy machine was the windmill. There were a good number of participants that did not answer these two questions or did not respond with answers that made sense.

4.4 Question 5 - Do you know how a windmill works? How?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Yes No explanation				1		1	2
No			3	1	2	3	9
Wind pushes sails to turn cogs to grind corn[1]			4	5	1	1	11
Spins to grind grain/make flour/wind spins to do thing[1]	3	2		2	1		8
Turns around/wind blows and it turns around[2]	4	2		1		1	8
Blades spin, moves polls to create electricity[3]		1		1		1	3
It spins the wind[2]	2						2
Wind blows, turns around shaft, turns instruments to generate magnetic field[3]			1	1			2
Cogs, Cogs to mechanics[5]					1		1
Cuts corn[4]	1						1
Gets water power going[4]				1			1
Machine with wind[2]					1		1
Millstone grinds weeds[4]		1					1
Opposite from fan[5]					1		1
Turns because of high and low pressure[2]				1			1
Wind blows cells drives machines inside[2]		1					1
							53

Trends

- [1]**Mechanics:**
  - When asked to explain how a windmill works, only 36% of the participants said that wind pushes sails to turn cogs. Of these people some said that the cogs were used to grind corn, grind grain, or make flour.
- [2]**Simple Mechanics:**
  - Approximately 25% of people could only tell us that the wind spins the blades of the windmill.
- [3]**Electronics:**
  - Approximately 19% of people mentioned that windmills generate electricity or use magnetic fields in some way.

Question 5 cont.

- [4]**Products:**
    - Three people (approximately 6%) mentioned products or tasks that windmills perform such as, cuts corn, gets waterpower going, or millstones grind weeds.
- [5]**Other:**
    - One person mentioned that cogs were used in windmills. While another participant said, "that they just work the opposite of a fan."
- **No knowledge:**
    - Nine of our participants (approximately 17%) had no idea how a windmill works.

In general, most people have a basic or partial understanding of how a windmill works. This leaves approximately 20% of the participants with little knowledge.

4.5 Question 6 - Do you know how a wind turbine works? How?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Wind turns turbine to create power[1]	3	2	4	3		1	13
No		2	2	4		2	10
Does something with electricity[2]				1	1	2	4
Produces energy into electric energy[2]		1			3		4
Turns around/wind blows and it turns around[3]	3			1			4
Connected to a generator[4]				2		1	3
Air plane blades[4]				1		1	2
It spins the wind[3]	1	1					2
Wind turns sails, turbine at top produces energy which travels town pole to station and then to grid[1]		1	1				2
Faster, modern[5]					1		1
Harness electricity don't know how[2]				1			1
More efficient[5]					1		1
Noisier[5]					1		1
Power[2]					1		1
Should look like windmills[5]						1	1
Used for oil? [6]						1	1
Wind blows, turns around shaft, turns instruments to generate magnetic field[2]			1				1
Wind turns propeller to generate friction to create electricity[1]				1			1
Yes No explanation				1			1
							54

Trends

- [1]**Mechanics and Power (16):**
  - Nearly one third of the participants knew that the blades of a wind turbine turn to generate electricity.
- [2]**Power (16)**
  - Another 30% of the participants only mentioned that wind turbines have something to do with power or electricity.
- [3]**Mechanics (6):**
  - Only 11% mentioned that the blades of the turbines spin in the wind.

Question 6 cont.

- [4]**Parts (5):**
    - Five people mentioned parts of a wind turbine including generators and blades.
- [5]**Affects (4):**
    - Four people responded about wind turbines in general as being noisy, faster, more modern, and more efficient.
- **No knowledge (10):**
    - Nearly nineteen percent of our participants had no idea what a wind turbine was.

Similar to the answers given in question five for windmills, the responses given to question six show that people have a general sense of what a wind turbine is used for. However, nearly half of our respondents did not know what a wind turbine was used for.

4.6 Question 7 - Which of these countries do you think use wind energy?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Holland	8	5	8	12	6	6	39
Great Britain	7	6	6	12	7	5	36
America	6	6	6	9	6	4	31
France	8	6	3	6	6	2	25
Italy	6	4	4	2	4	1	17
South Africa	2		2	3	3	2	9
Egypt	3		2		3	2	7
India			2	1	4	1	4
None		1					1
							169

Holland	78%	Correct
Great Britain	72%	Correct
America	62%	Correct
France	50%	Correct
Italy	34%	Correct
South Africa	18%	Correct
Egypt	14%	Correct
India	8%	Correct
None	2%	Incorrect

Trends

When asked to pick countries, the participants seemed unsure about which countries used wind energy.

4.7 Question 8 - Do you think wind power should be used more or less? Why?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
More	9	5	3	10	6	6	39
Less	1		2	2	1		6
Depends			1	1			2
No opinion	2						2

WHY

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Good For Earth/ Natural/ Good for environment/ Won't effect ozone/Not much Pollution/Clean[1]	6	3	2	5	5	2	23
Renewable[1]		1	1	3	1	1	7
No Reason[4]	2	1		1			4
Not expensive/Cheap[3]			2	1		1	4
Better then [3]		2	1				3
Good Source/Not harmful[1]	1	1			1		3
Free[3]			1	1			2
Lots of space required[2]			2				2
Noise[2]			1		1		2
Not dependable/Too hard because don't know when wind will come[2]	1					1	2
Saves worlds resources/Energy is depleting[1]	1			1			2
Ugly/Were people can't see it[2]				1		1	2
Britain has a lot of wind[4]						1	1
Depends on Country[3]			1				1
Depends on looks[3]				1			1
Does not produce enough power[2]				1			1
if you can harness it[4]				1			1
Makes electricity [4]	1						1
More Food[4]	1						1
Need a better way to harness it[2]				1			1
Not practicable[2]				1			1
Offshore[4]			1				1
Pretty[1]			1				1
Use other resources[2]			1				1
Maintenance[3]					1		1
Fall and kill people[2]					1		1
							70

Question 8 cont.

Trends

- [1]**Good for the environment (36):**
    - More than half of the participants said they thought that wind energy should be used more because it is good for the environment.
- [2]**Bad Qualities (13):**
    - Nineteen percent of the participants had negative things to say about wind energy. Participants said that wind power was noisy, not practical, ugly, and requires too much space. They suggested that wind power sources do not generate enough electricity to make it worthwhile.
- [3]**Good qualities (12):**
    - Approximately seventeen percent thought wind turbines had good qualities other than those relating to the environment. Wind machines were described as pretty, cheap, free, and practical.
- [4]**Other (9):**
    - Nine people had other things to say about wind energy. Some said that Britain has a lot of wind. Others said that wind machines should be used offshore.

Seventy-nine percent of the participants said that wind energy should be used more. Although their reasons vary, the most common reason is that it is good for the environment. The 21% of people that have no opinion or are against using wind energy are concerned that it is not practical, the aesthetics of wind machines poses a problem, and the maintenance that goes into sustaining the wind turbines poses a problem.

4.8 Question 9 - Which of these words would you use to describe wind power?

Raw Data

	8 to 12	13 to 15	16 to 18	19 to 35	36 to 50	> 50	Total
Clean	7	6	7	12	6	7	27
Renewable	8	7	6	9	3	5	26
Interesting	8	6	6	1	3	5	25
Safe	7	6	5	12	4	7	25
Cheap	4	7	4	3	5	2	17
Beautiful	1	2	3		2	2	8
Noisy	3	1	3	3	2	1	8
Expensive	1		2	4	1	1	4
Old	1		2	1	1	1	4
Dangerous		1	1		1		2
Ugly		1		1	1	1	2
Polluting	1						1
							149

Trends

Clean	54%
Renewable	52%
Interesting	50%
Safe	50%
Cheap	34%
Beautiful	16%
Noisy	16%
Expensive	8%
Old	8%
Dangerous	4%
Ugly	4%
Polluting	2%

APPENDIX C – Energy Team Discussion Results

Discussion group: Energy Team

Date: 08/02/00

Format:

- Introduction
  - Briefly describe our project
  - Explain that we are only showing them five ideas and not all of our ideas
- Show pictures
- Discuss
  - Question
    - What aspects of this exhibit do you predict will not work?
    - Do you have any suggestions to fix these problems?
    - Do you think that this exhibit will be accessible to all visitors?
    - Do you have any suggestions that would make the exhibit better?

Participants:

Claire Bonham-Carter, Peter Davison, Sophie Duncan, and Allen Morton

Results:

Wind Table

- Constant wind flow vs. button
  - If this were a group activity it would be hard to have start and stop times.
- Removable turbine problem
- Attach the wind turbines to chains
- Have a switch board in which you can just turn different turbines on and off
  - This would not work to see the aesthetics
- Possibly have the angle vs. wind speed in another exhibit (different from placement)
  - Do not necessarily need to get across a bunch of ideas
- Have the exhibit explain where turbines should be place to generate energy for certain areas
  - What would be the wind installations suitable for the three areas (city, farm, shore community)? What is the appropriate location for the wind turbine? Possible use the exhibit to explain this
  - Energy flow results: has a problem when multiple people are working on the same exhibit because some may want to power the city and other the shore community. This would work better as an exhibit on the web when one person can explore the proper placement of wind turbines for the certain areas.
- Have protesters by the city
- Scale of the project may make aesthetics irrelevant

Wind Tunnel

- Have multiple turbines
    - Use more of the wind tunnel space
    - Visitors can interact with multiple turbines and see how each one works differently
    - Also see if two smaller one will equal the output of a larger one.
    - Different turbine types
        - Size of blades, number of blades, axis direction
    - Safety: If visitors are going to change turbines they cannot be allowed to touch the turbine while it is moving.
        - Door must be locked to start wind
        - Have a slide they can pull to change what turbines are in the wind
- Have the output on the tunnel power the air that flows over the wind table and/or other things (video camera, music, underground train)
- If a wind tunnel is going to be built, one should try to get the most out of it.
- Have a rotating landscape in the wind tunnel

Where in the world

- Concerns with making videos
  - Expensive to make or hard to find
- Have a second set of buttons next to the monitor
  - Enable everyone to reach them (children and disabled issue)
- The buttons are large so you could not have more then on in some countries.
- Display how much power is produced by each wind farm location
- What materials is the globe going to be made out of
- Find locations for major wind farms
- Spinning issue
  - It should not spin
- Comparison between
  - Output (quantity and styles), use (battery, grid, houses), and technologies

Hearing the wind

- Talk to Nick Smith about getting sounds
- National Sound Archive
- On other side of Imperial College
- Borrow sounds for development only later the museum can work out a deal to get them for the exhibit
- Select the most irritating sound
- Take a survey of the visitors

- Have each button compare a different noise to the noise of a wind turbine
- By having the wind turbine a constant the other buttons rocker switches to another sound

Time period matching game

- Have a middle square that will have the applications
- Include applications in different countries
- Testing
- Get images and see if people can match them
- Get a video animation to see how wind machines work in that time period
- On actual rotating block or on monitor

    Videos are expensive and hard to find

APPENDIX D – Exhibit Evaluation Results

Exhibit Evaluation Report

Where in the World
And
Wind Power Matching Game

National Museum of Science and Industry
Energy Gallery
Wind Energy Exhibit

Table of Contents

1 Introduction

In development of the exhibits for the wind energy portion of the Energy Gallery, we tested two exhibits with members of staff and museum visitors to get a better understanding of where the exhibits need improvement. Laura Domey, Wendy Kogel, and Benjamin Newton tested *Where in the World* and *Wind Power Matching Game* on the twenty-third and twenty-fourth of March 2000.

We tested these exhibits using computer-based models of them. We tested the *Wind Power Matching Game* with twenty-four people; six were museum staff, thirteen were museum visitors, and five were students from Worcester Polytechnic Institute (WPI). The *Where in the World* exhibit was tested with six museum staff members, five visitors, and ten WPI students.

For each exhibit, the test participants were sat down in front of the computer running the mock-up. They were then allowed to manipulate the exhibit however they saw fit. They were given no instruction and were told that the administrator of the test could not answer any questions. The data was collected through observation of the participants' actions and through a questionnaire that was administered immediately after the participant was finished with the exhibit. This report is meant to organise the raw data collected from the questionnaire and should be used for qualitative analysis only.

2 Wind Power Matching Game

2.1 Summary

During testing of this exhibit, 83% of the participants said that they found it interesting. Our observations revealed that 19 out of 24 visitors began by reading the instructions. When asked about the message of the exhibit, the most common response was that it served to teach people about the different types of wind machines. Some of the visitors encountered difficulties in identifying some of the pictures. The picture of the water pump and the grain caused the most problems. When asked to rate the exhibit on a scale of 1 to 5, 1 being uninteresting and 5 being very interesting, the average of all responses was 3.6.

2.2 Questionnaire

Time-Period Matching Game

Hello my name is ... and I work for the Science Museum. We are testing an exhibit for a new gallery we are developing. Would you and your child(ren) be interested in spending about 5 minutes helping us test them out? *{If yes take into testing area}*. This is only a prototype version of the final exhibit so there is still a lot we need to improve but we want to see what people think of it. Just pretend you came across it in the gallery.

Specific points to look out for	Describe step by step what happens as if you were dictating it out loud to someone.
How do visitors react to the exhibit initially?	....
What do visitors say to each other and to you?	....
Do they experience any difficulty with the instructions?	....
How quickly do they get the right answer? (1st, 2nd, 3rd try)	....
Do they appear to read the information displayed?	....
How long does it hold their attention?	....
Choose more info?	....

go on to back of sheet if necessary

1. What do you think this exhibit is trying to show people? {Prompt: What do you think we are trying to say to visitors about wind?}

2. Did you find the information it provided interesting?

3. Did you recognise all of the pictures?

4. What did you like best about this? What did you like about that?

5. What did you like least about this? How can we improve this?

6. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in using this exhibit in an exhibition?

1 2 3 4 5

7. Which of the following age groups do you fit into?

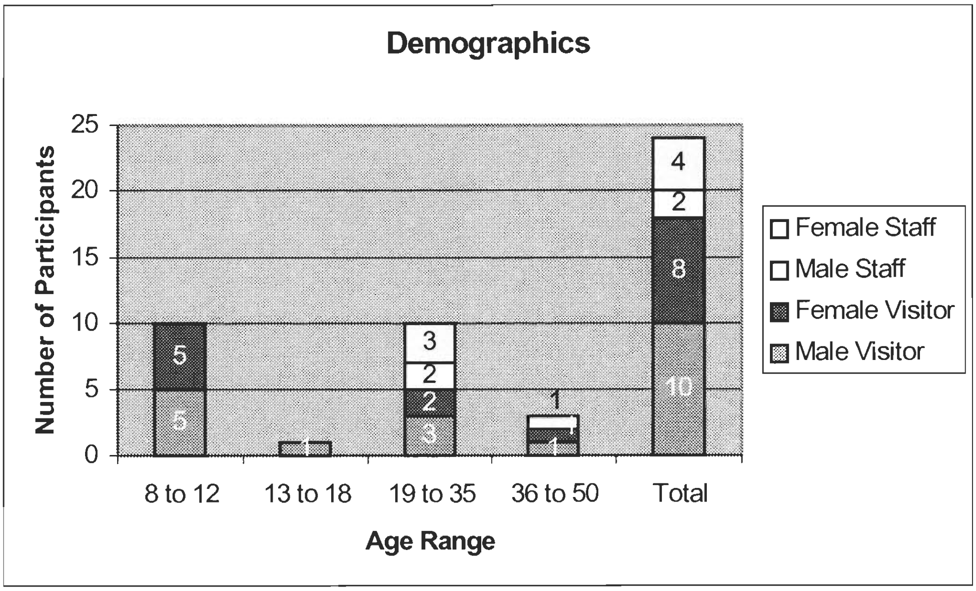
8-12 13-18 19-35 36-50 >50

male / female

At end of interview thank and hand out stickers.

Interviewer Date

2.3 Demographics



We had a total of 24 participants. Eighteen were museum visitors and six were museum staff.

2.4 Initial Actions

	Staff	8 - 12	13 - 18	19 - 35	36 - 50	Total
Read instructions and experimented with buttons	2	10		5	2	19
Click on images		1	1			2
Look at each picture	1	1				2
Click arrows	1					1
Click instructions	1					1
Look at all buttons and images	1					1
Said it looks like Challenge of Materials	1					1

85% of the visitors read the instructions first while the initial actions of the members of staff varied.

2.5 Participants' comments

Comments during testing:	8 - 12	13 - 18	19 - 35	36 - 50	Total
Nothing said.	5		3	1	9
Can I change the picture/Can I move both?		1	1		2
Waited for parents to explain	2				2
1/2 town of Swaffham				1	1
Are those arrows?			1		1
Can I change the top as well?				1	1
Does that mean I got it right?			1		1
How do I ...	1				1
I just guessed that.	1				1
Match top with bottom.		1			1
Try this... that matches.	1				1

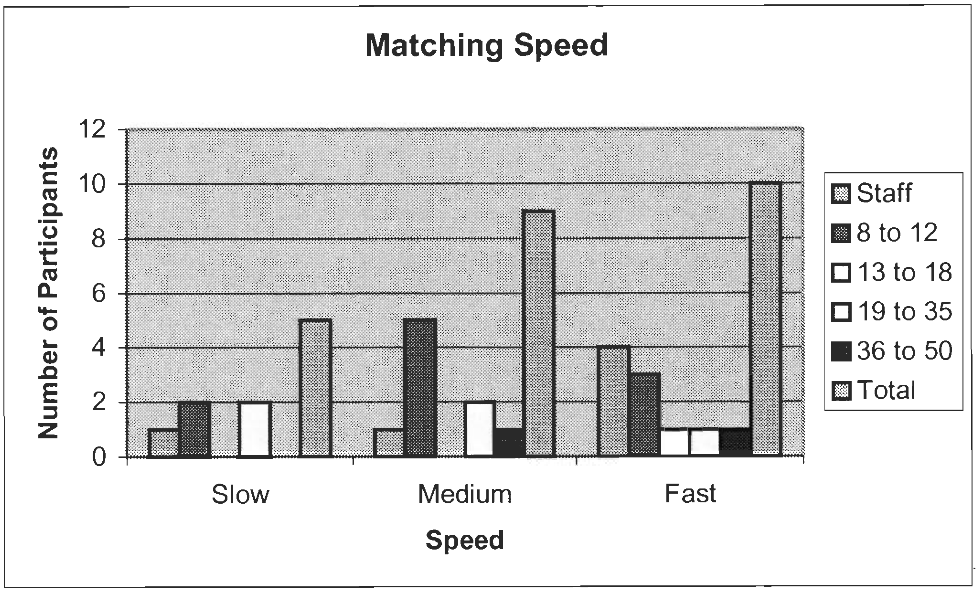
The members of staff tested this exhibit individually and did not make any comments. Nine out of twenty-one visitors did not have anything to say.

2.6 Did the participant have any problems understanding the instructions?

Problems with instructions:	8 - 12	13 - 18	19 - 35	36 - 50	Total
No	8		5	1	14
Seem to want more	1				1
Did not know to read them		1			1
Parent explained	2				2
Re-read				1	1

The members of staff did not experience any problems with the instructions. Only five participants of twenty-four had any difficulty with the instructions. Of those five, two had their parents read them the instructions.

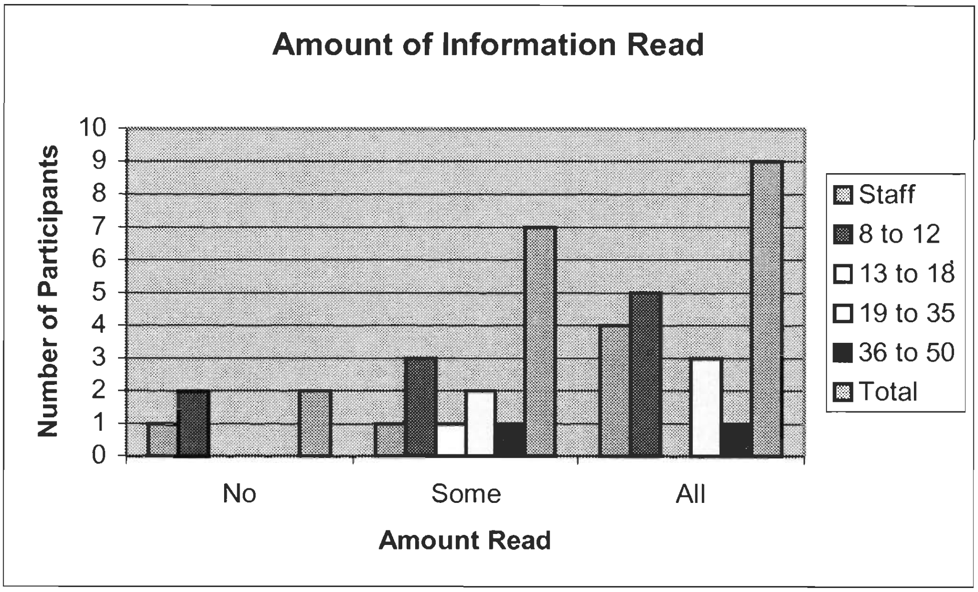
2.7 How quickly was the participant able to make a correct match?



- Slow: 3 matches on 2nd try or 2 matches on 3rd
- Medium: 2 matches on 2nd or 1 match on 3rd try
- Fast: 3 matches on 1st try

Most people did this relatively quickly, with museum staff working the most efficiently.

2.8 How much information did the participant read?



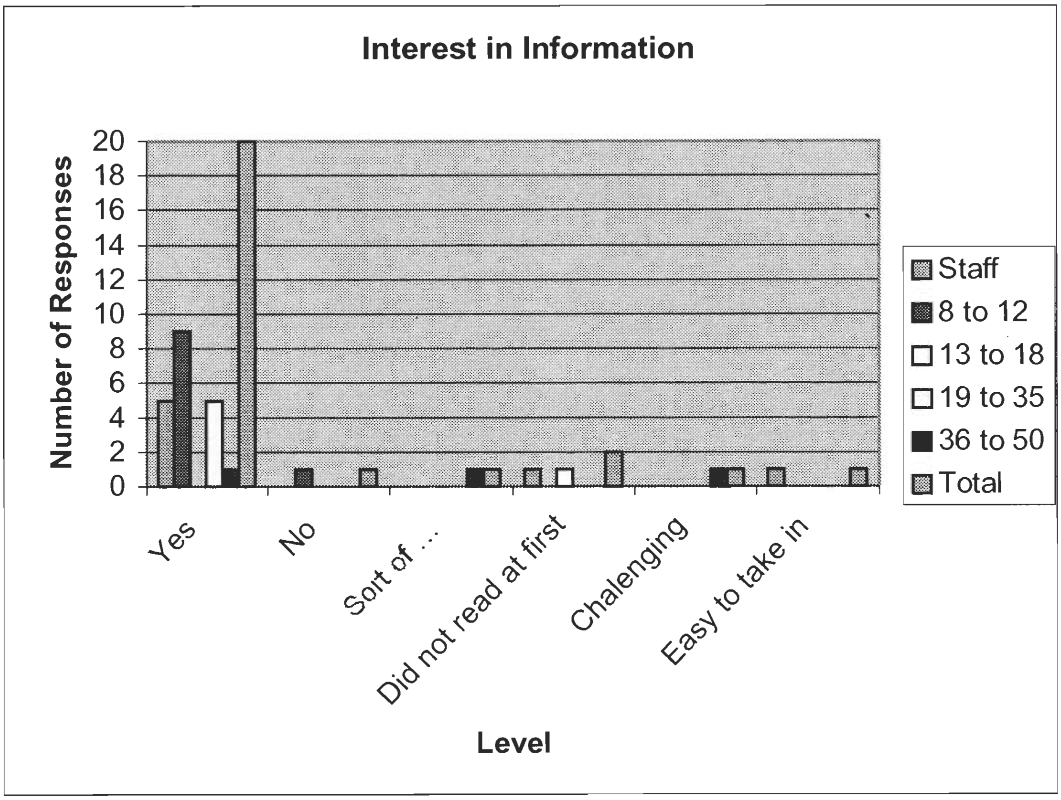
Nine out of twenty-four people seemed to read all the information, with most of them being staff and children between the ages of eight and twelve. Seven out of twenty-four or 29% only partially read the information and two people did not read it at all.

2.9 What did the participant think the exhibit was about?

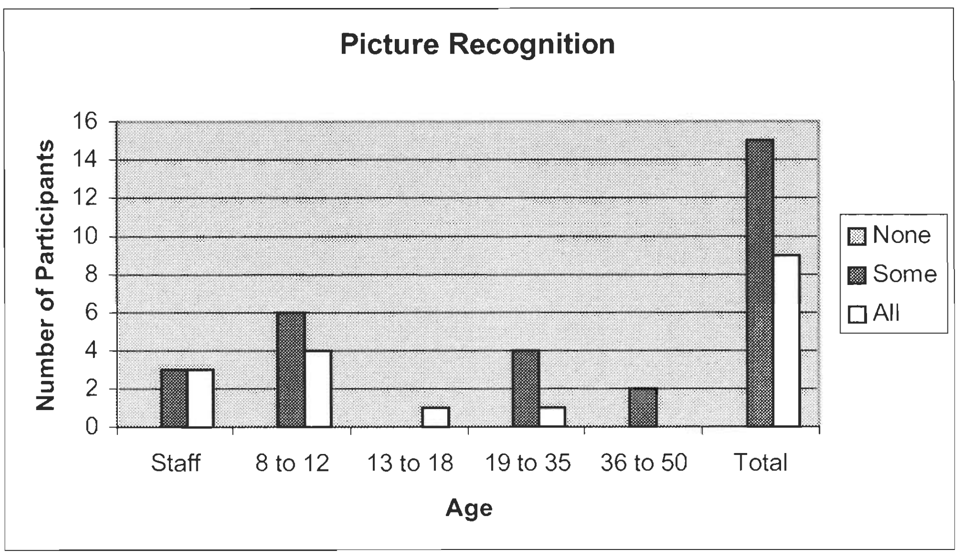
	Staff	8 - 12	13 - 18	19 - 35	36 - 50	Total
What different wind turbines are used for, Wind power can be used for different things, Wind turbines and what they do in different time periods, What how they work to what they make	4	1	1	5	1	12
How windmills work / Knowledge of cogs and mechanics		5				5
Links/matching/what goes with what		3	1			4
Energy/converting energy/Reusable sources	1	1			1	3
No comment		2				2
Environment/Green sources					1	1
Shows we gather wind energy for a purpose.	1					1
Wind		1				1

Of the twenty-nine responses to this question, twelve dealt with the message that wind machines are used for varying purposes.

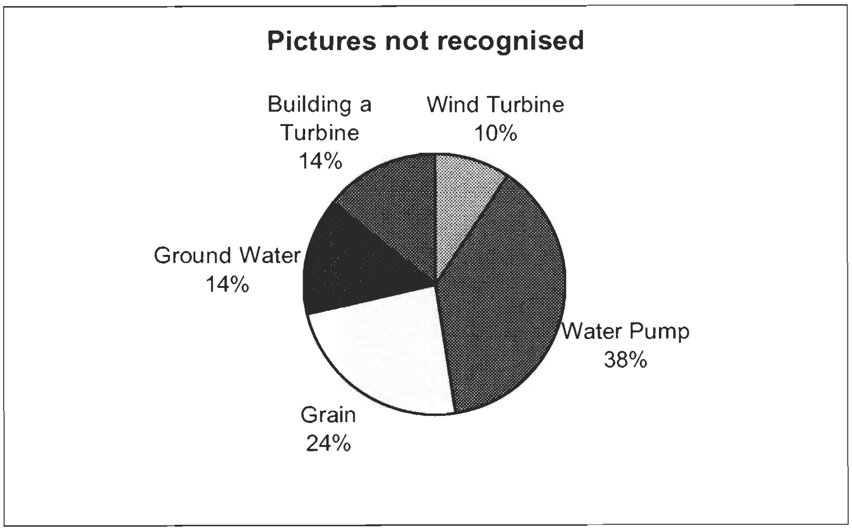
2.10 Did the participant find the information interesting?



Twenty of twenty-four participants said that the information that was provided in this exhibit was interesting.



2.11 Did the participant recognise the pictures?



This graph depicts which pictures were not recognised. Fifteen participants did not recognise all of the pictures.

Item not recognised

	Staff	8 - 12	13 - 18	19 - 35	36 - 50	Total
Water Pump	3	4		1		8
Grain		1		2	2	5
Building a Turbine		1		2		3
Ground Water		2		1		3
Wind Turbine		2				2
Pilings						0
Windmill						0

2.12 What part of the exhibit did the participant like the best?

	Staff	8 - 12	13 - 18	19 - 35	36 - 50	Total
No Comment		2		1	1	4
Pictures	1	2	1			4
Animation		1			1	2
Computer/Interface		1		1		2
Entertaining/Play with it	1			1		2
Big Green Button		1				1
Electricity		1				1
Finding right one		1				1
Fun to Match		1				1
Interesting				1		1
Like seeing real world pictures	1					1
Matching to get info	1					1
Perfect amount of text	1					1
Scrolling Pictures	1					1
Simple	1					1
Sound				1		1

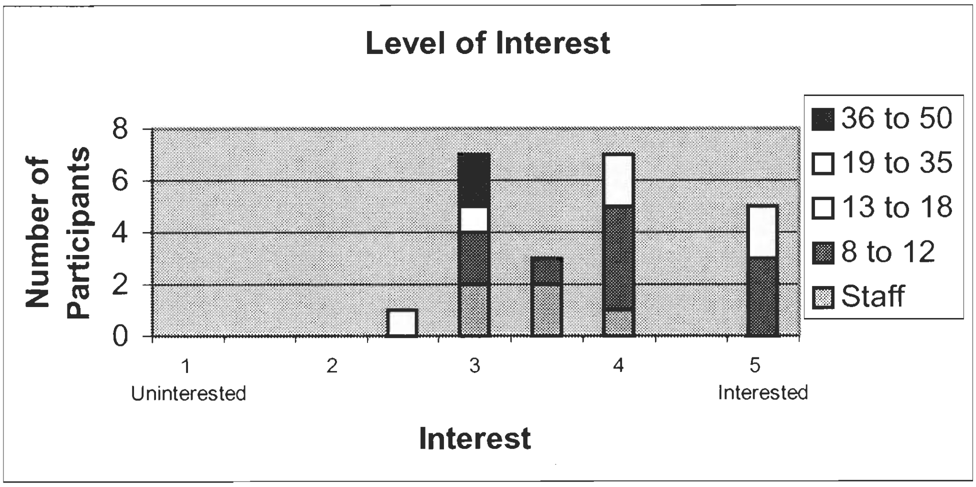
The participants have a large variety of responses to answer the question of what they liked the best. The most common responses were 'no comment' and 'pictures.'

2.13 What part of the exhibit did the participant like least?

	Staff	8 - 12	13 – 18	19 - 35	36 - 50	Total
No Comment		4				4
Getting it wrong		1		1		2
More things to match to make it harder	1			1		2
Reward for matching	2					2
Too small	1				1	2
Windmill		2				2
Arrows fade into background				1		1
Big green button should say try this or test your match all the time	1					1
Concepts are difficult to figure out					1	1
Did not know what to do next				1		1
Did not know what wind turbine construction image was				1		1
Don't like how pictures disappears behind text	1					1
Education		1				1
Images repeated	1					1
Instructions back on screen				1		1
Laptop			1			1
Make answer disappear after click next	1					1
Make it a word matching game	1					1
More clarification on relation of images	1					1
Pictures should be of similar styles	1					1
Thinking		1				1
Too simple	1					1
Wants more pictures		1				1

The participants had a large variety of responses to this question. Because most of the participants made different comments we looked at each suggestion individually to determine if their suggestion will improve the exhibit to benefit all visitors.

2.14 What was the participants' level of interest?



Seven people rated this exhibit a three on a scale of one to five where five is most interested. Another seven rated it at four, while five people rated it at five. Twenty-three people of the twenty-four people that we talked to about this exhibit were more interested than disinterested in it. The average of all responses was 3.6.

3 Where in the World

3.1 Summary

Most visitors explored all of the countries though they said that information that was presented was too dense. Visitors did not have trouble with the size of the buttons or with the instructions that were provided to them. Some of the visitors desired a button that would return them from a country to the world map. Most visitors said that the exhibit was about how wind energy is used in different countries. A little less then half of the participants found the information that was presented interesting. The most frequent level of interest was four. The average of all responses to this question was 3.1.

3.2 Questionnaire

Where in the World

Hello my name is … and I work for the Science Museum. We are testing an exhibit for a new gallery we are developing. Would you and your child(ren) be interested in spending about 5 minutes helping us test them out? *{If yes take into testing area}.* This is only a prototype version of the final exhibit so there is still a lot we need to improve but we want to see what people think of it. Just pretend you came across it in the gallery.

Specific points to look out for	Describe step by step what happens as if you were dictating it out loud to someone.
How do visitors react to the exhibit initially?	…………………………………………………………
	…………………………………………………………
What do visitors say to each other and to you?	…………………………………………………………
Do they experience any difficulty with the instructions?	…………………………………………………………
	…………………………………………………………
	…………………………………………………………
How many different locations do they investigate?	…………………………………………………………
	…………………………………………………………
Do they experience any problems with the size of the buttons?	…………………………………………………………
	…………………………………………………………
Do they appear to read the information displayed?	…………………………………………………………
	…………………………………………………………
How long does it hold their attention?	…………………………………………………………
	…………………………………………………………
Choose more info?	…………………………………………………………
	go on to back of sheet if necessary

1. What do you think this exhibit is trying to show people? {Prompt: What do you think we are trying to say to visitors about wind?}

2. Did you find the information it provided interesting?

3. Did you recognise all of the countries?

4. What did you like best about this? What did you like about that?

5. What did you like least about this? How can we improve this?

6. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in using this exhibit in an exhibition?

1 2 3 4 5

7. Which of the following age groups do you fit into?

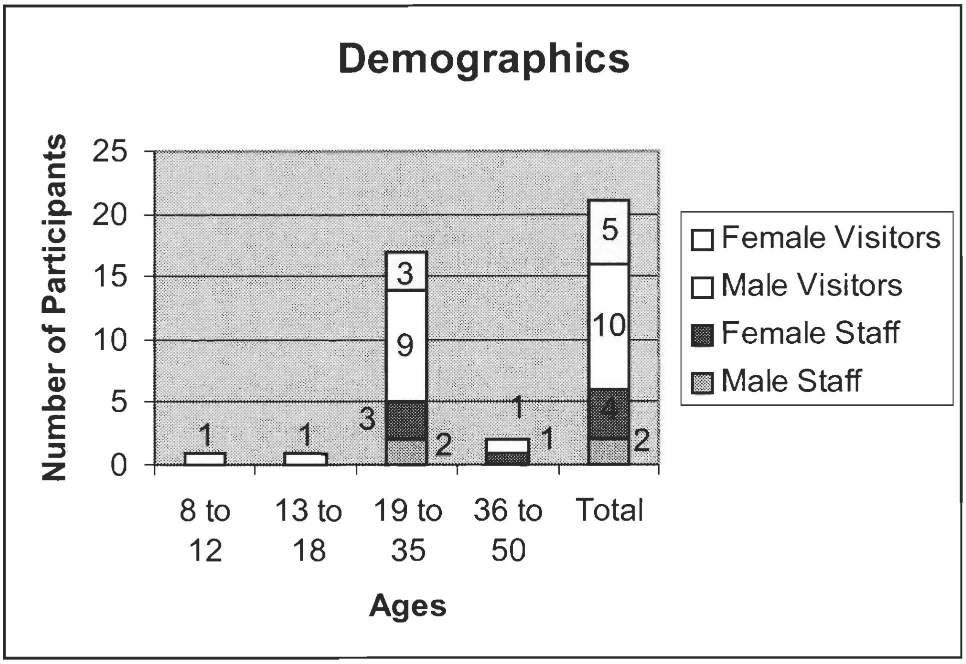
8-12 13-18 19-35 36-50 >50

male / female

At end of interview thank and hand out stickers.

Interviewer Date

3.3 Demographics



We tested *Where in the World* with a total of twenty-one people. There is a large population of nineteen to thirty-five year olds because most of the museum staff and all of the WPI students were in this age group. We did not see a problem with the skewed age distribution for two reasons. The first reason is the museum staff are trained to test museum exhibits. The second reason is we believe that testing with WPI students was beneficial because they would be more critical of our exhibits than most visitors.

3.4 Initial Reactions

	Staff	8 - 12	13 - 18	19 – 35	36 - 50	Total
Click on Map/Buttons	4			9		13
Look at places		1		2		3
Uses text links				3		3
Asks question			1	1		2
Confused					1	1
Difficult to get around	1					1
Read bottom				1		1
Reads out loud				1		1
Want to try it	1					1

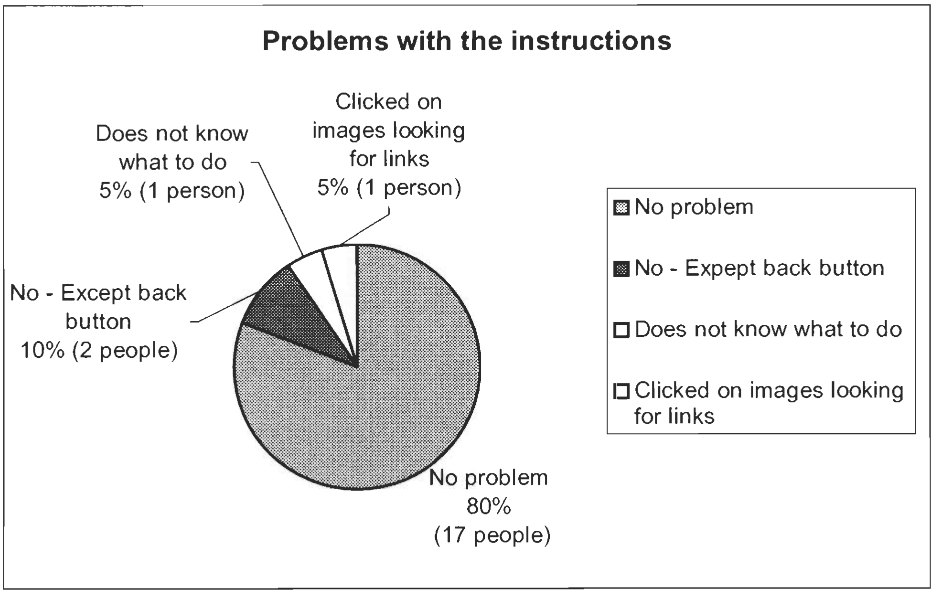
Most of the participants used the buttons on the map initially to explore the countries.

3.5 Participants' Comments

	Staff	8 - 12	13 – 18	19 - 35	36 - 50	Total
Back buttons? How do I get back? (from country to map)	2			5		7
Can I click on a link?		1		1	1	3
Nothing to say.				3		3
Lots to read / Do I have to read these?				2		2
No Pictures?				2		2
Blue Buttons.				1		1
Can I go to any of these countries?				1		1
Did I already go here?				1		1
<Laugh> England is 28 time windier then Denmark.	1					1
Linear arrangement, wow!				1		1
Having no pictures is less interesting.				1		1
What is a terawatt hour?				1		1
What should I do?			1			1

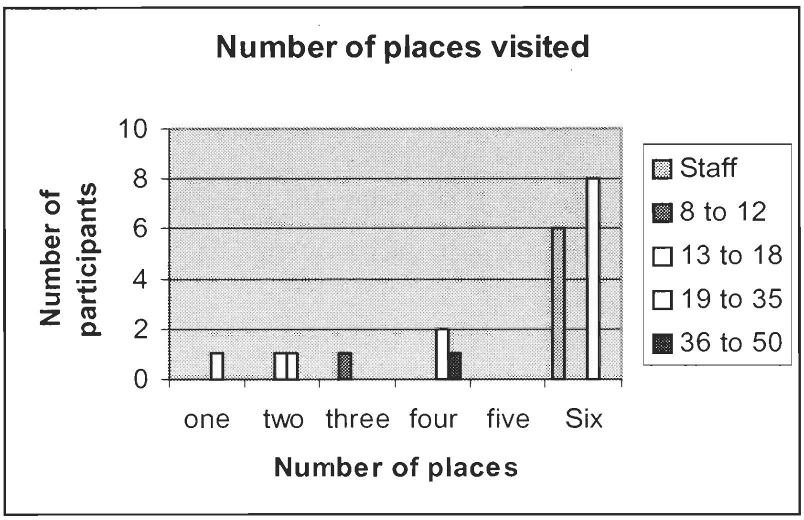
Seven participants mentioned that they would like back buttons to help them navigate around the web site. The other comments that we received were more about confirming what the participant wanted to do with the exhibit (Can I click on a link?, What should I do?, Do I have to read these?, and Can I go to any of these countries?)

3.6 Did the participant have any problems with the instructions?



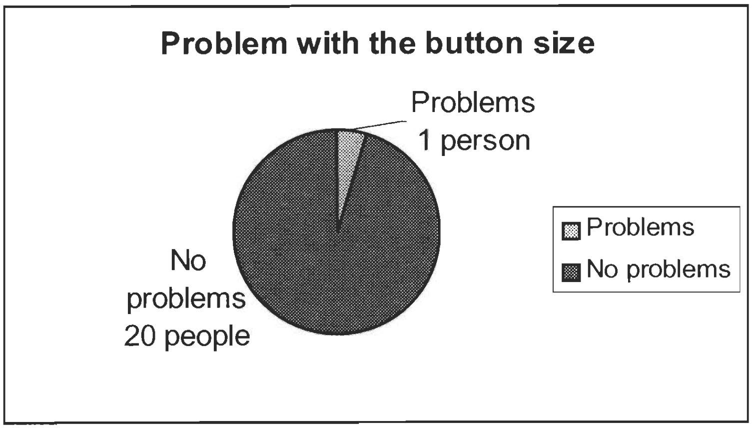
Only two people had difficulty using this exhibit. Two of the remaining nineteen people wanted back buttons while the other seventeen had no problem using the exhibit.

3.7 How many countries did the participant view?



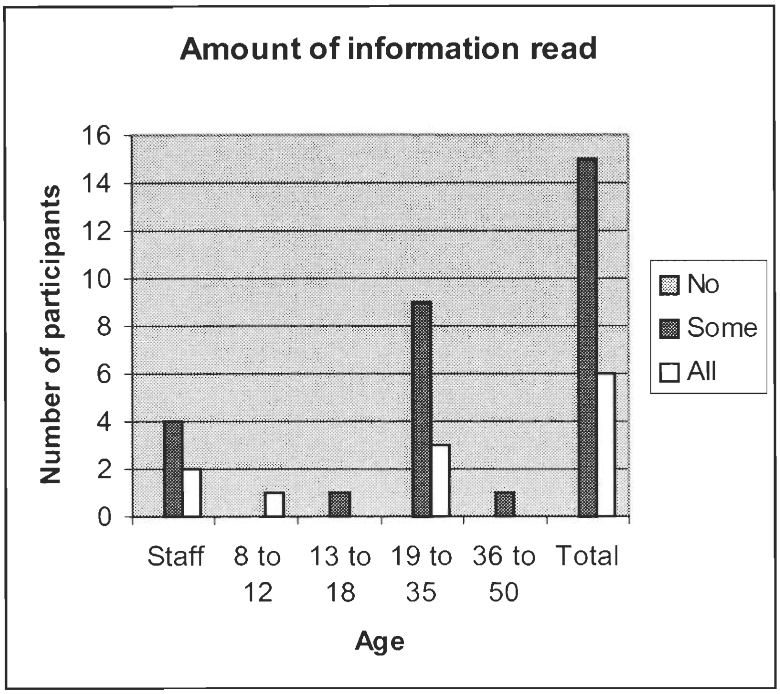
The entire staff visited every location. About half (eight of fifteen) of the other participants visited all six locations.

3.8 Did the participant have problems with the size of the blue buttons?



Only one participant had trouble using the blue button links to the other pages.

3.9 How much text did the participant read?



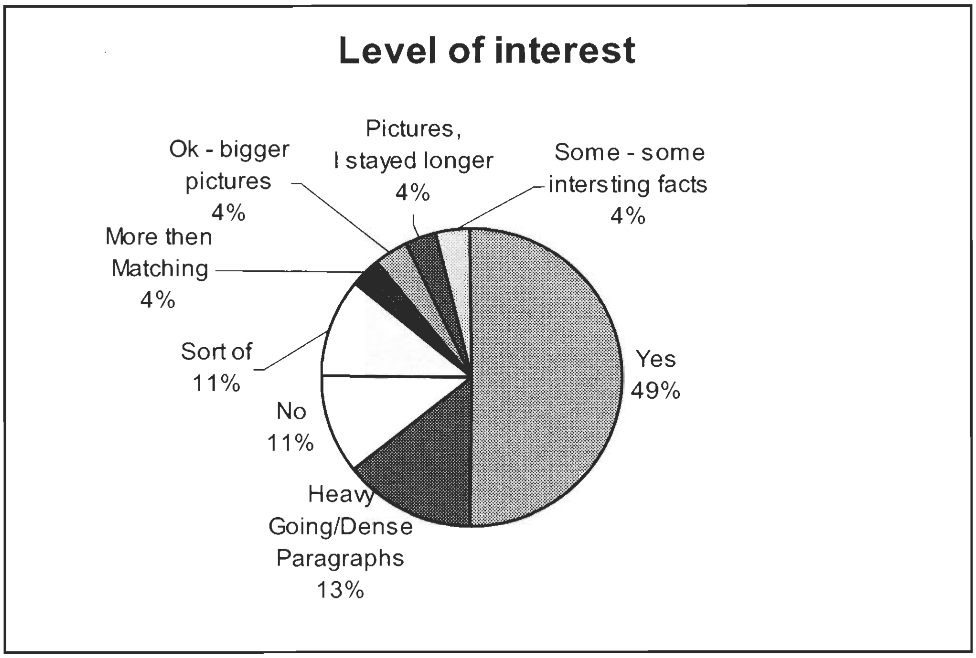
Fifteen of the participants seemed to read some of the information gathered. Six seemed to read all the information.

3.10 What did the participant think the exhibit was about?

	Staff	8 - 12	13 – 18	19 - 35	36 - 50	Total
Wind energy is used in all different countries, How / When / Where wind energy is used around the world, Wind energy is used in various places	5			9		14
Wind Power / Wind Energy			1	1	1	3
Applications of Wind Energy				2		2
Environment		1		1		2
Climate Conditions				1		1
History				1		1
New approaches to energy	1					1
No 3rd World				1		1
People are building lots of turbines	1					1
Science				1		1
Very Political	1					1
World		1				1

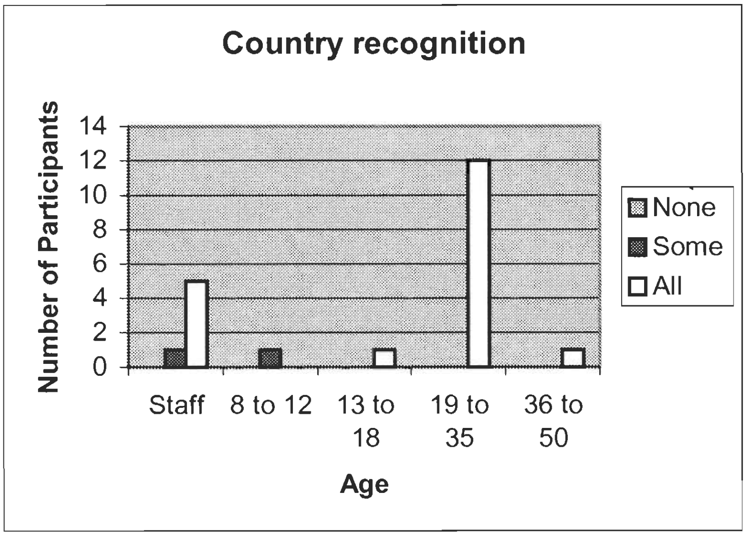
Fourteen, a 7 to 1 ratio of participants, mentioned the message that the exhibit is supposed to convey; wind energy is used in many different countries. The rest of the responses for this exhibit varied greatly from participant to participant.

3.11 What was the participants' level of interest?



A little more then half (14 of 21) of the participants thought that this exhibit was interesting. Three people said that it was sort of interesting or not interesting at all. Four participants did not like the dense paragraphs of information.

3.12 How many countries did the participant recognise?



Only two participants did not recognise all of the countries. A child between the ages of eight and twelve did not recognise Italy, Greece, and United States (California). The other was a member of staff who did not recognise the United States (California).

3.13 What did the participant like best?

	Staff	8 - 12	13 - 18	19 - 35	36 - 50	Total
Pictures				5		5
Front page, Overview global perspective, 1st screen	2			2		4
Can click on map			1	2		3
Info, Text not to long, Descriptions	1			2		3
Comparing different regions	2					2
India				1	1	2
Interesting facts	2					2
Colourful				1		1
Comparisons to England	1					1
England/Denmark	1					1
Info on U.K.		1				1

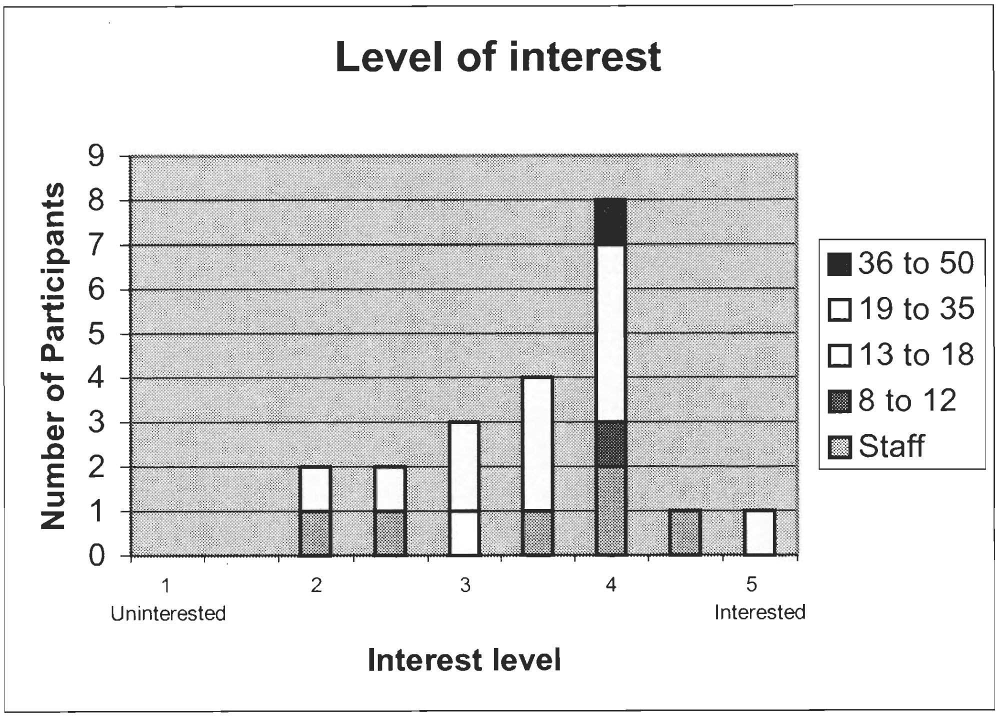
The responses for this question vary but the most frequent response is that they like the pictures.

3.14 What did the participant like least?

	Staff	8 - 12	13 – 18	19 - 35	36 - 50	Total
Too much text, Text is dull, Dense Paragraphs	4			3		7
No back button	2			3		5
Ones w/out pictures	3			2		5
Compare power use between countries	4					4
Charts to compare data	3					3
Needs more info		1		2		3
Add different types of wind machines	1					1
Bigger pictures			1			1
Colour				1		1
Facts first deeper info later on	1					1
Font Size (bigger)				1		1
Jet stream air flow see where windy	1					1
Lighten Tone of exhibit	1					1
Make Countries different colours				1		1
Make Europe Bigger				1		1
More colour			1			1
More relevant to me	1					1
Move navigation bar up				1		1
Needs bullets				1		1
No Comment					1	1
No explanation of what blue buttons do				1		1

Again the results for this section vary greatly from comment to comment. The most popular is that the text is too dense. The results from this section will be considered on an individual basis to determine if implementing the participants' suggestion will improve the quality of this exhibit.

3.15 What was the participants' level of interest?



Eighty-one percent of the participants rated this exhibit three or better on a scale from one to five. The most common interest level was four.

APPENDIX E – Contact Information

Sophie Duncan:

Energy Project
Science Museum
Exhibition Road
South Kensington
SW7 2DD

Tel: 020 7 942 4170
Fax: 020 7 942 4102
Email: s.duncan@nmsi.ac.uk

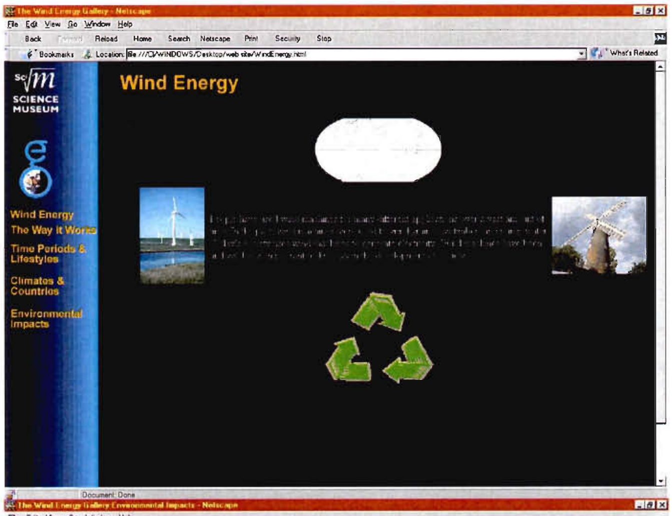
Worcester Polytechnic Institute:

Interdisciplinary and Global Studies Division
100 Institute Rd.
Worcester, MA
01609
USA

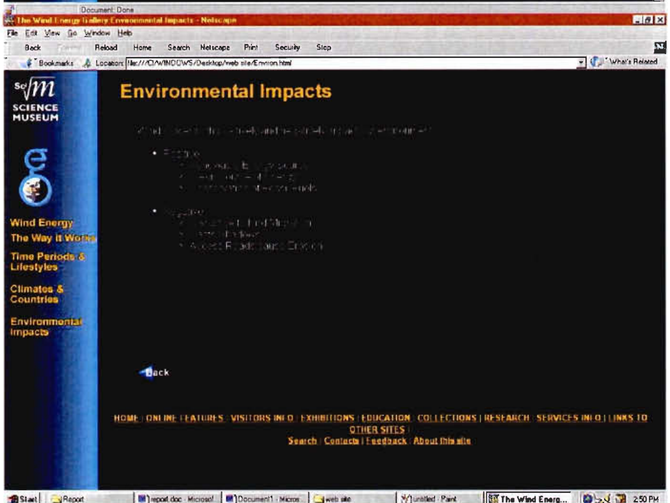
Tel: (508) 831-5547
Fax: (508) 831-5485

APPENDIX F – Wind Energy Web Page

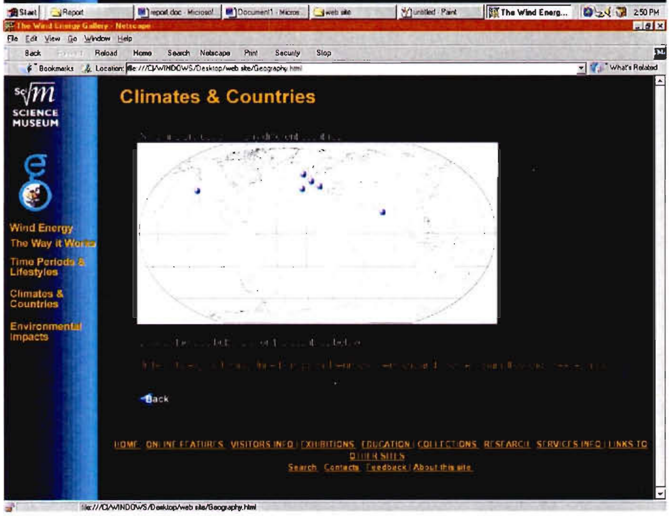
The following screen shots are of our virtual exhibit. The virtual exhibit explores wind energy through the four content topics: *The Way it Works, Time Periods and Lifestyles, Climates and Countries,* and *Environmental Impacts*.



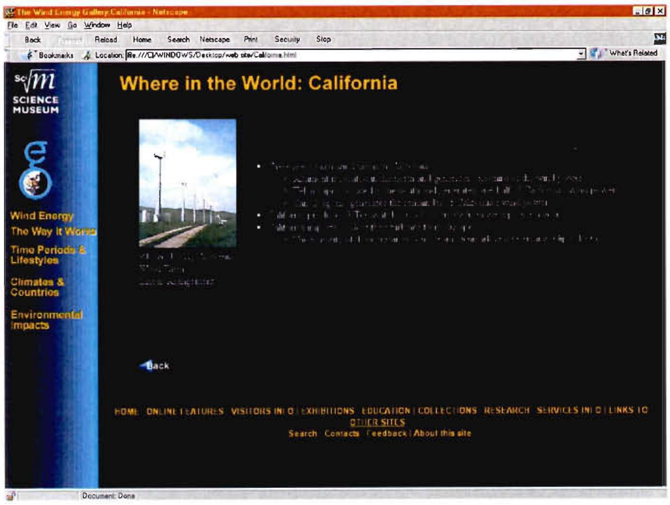
Left: main wind energy page



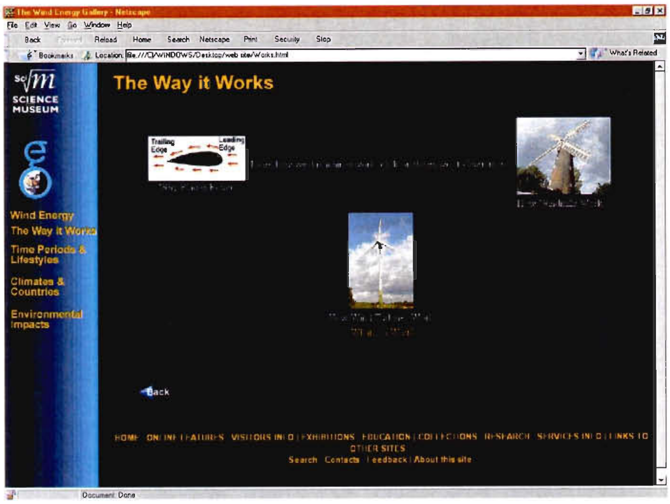
Left: Environmental Impacts page



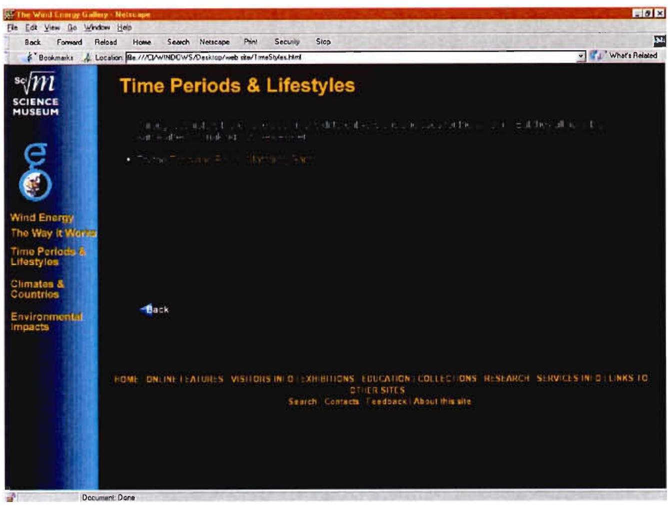
Left: Climates and Countries page



Left: Where in the world exhibit California page. Linked off the Climates and Countries page.



Left: The Way it Works page. Links to pages describing how a windmill and a wind turbine work. In addition, a page devoted to why the wind machine blades spin and what a watt is.



Left: Time Periods and Lifestyles page. Links to the Matching game.

APPENDIX G – Final Exhibit Template Sheets

The following pages in this appendix are composed of the museum's Exhibit Template Sheets for each of the final exhibit designs.

Exhibit Template Sheet

Project Title: Working Turbine

Exhibition/Area: Energy Gallery　　Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (***What is the wider exhibition/area content that the exhibit must fit into?***)

Show how to produce the maximum energy using wind machines.

Subject Matter: (***What must be in the exhibit?***)

Explain how a turbine's blades effect how much power is produced. The angle of the blade can be changed.

Target Audiences: (***Who is it for? NB. Groups not listed will not be catered for***)

Key stages 2 and 3

(*Include* prior knowledge assumed)

Know what a wind turbine is.

Cognitive Outcomes: (***Perception, memory, thinking***)

Understand that the angles of the blade affect the amount of power produced.

Affective Outcomes: (***Emotions, feelings, impressions***)

Satisfied that they produced X amount of electricity by changing the way the blade faces the wind.

Conative Outcomes: (***Will, intentionality, planning***)

Behavioural Outcomes: (***Movement, activities, habits***)

Project Title: Working Turbine | Date: 2000-02-21
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Idea

Description:

The visitor has the ability to turn a dial to change the angle of the blade, turn the entire turbine, or stop the turbine altogether. The visitor will then be able to see how much energy he or she produces by changing the different parameters.

Number of users/observers:

1 user 5 observers

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

3 inputs many outputs

Duration of activity:

1 minute

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Turn dial, press buttons

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, physical control

Attraction: (*How will it attract people and how will it keep them there?*)

The ability to power the machine

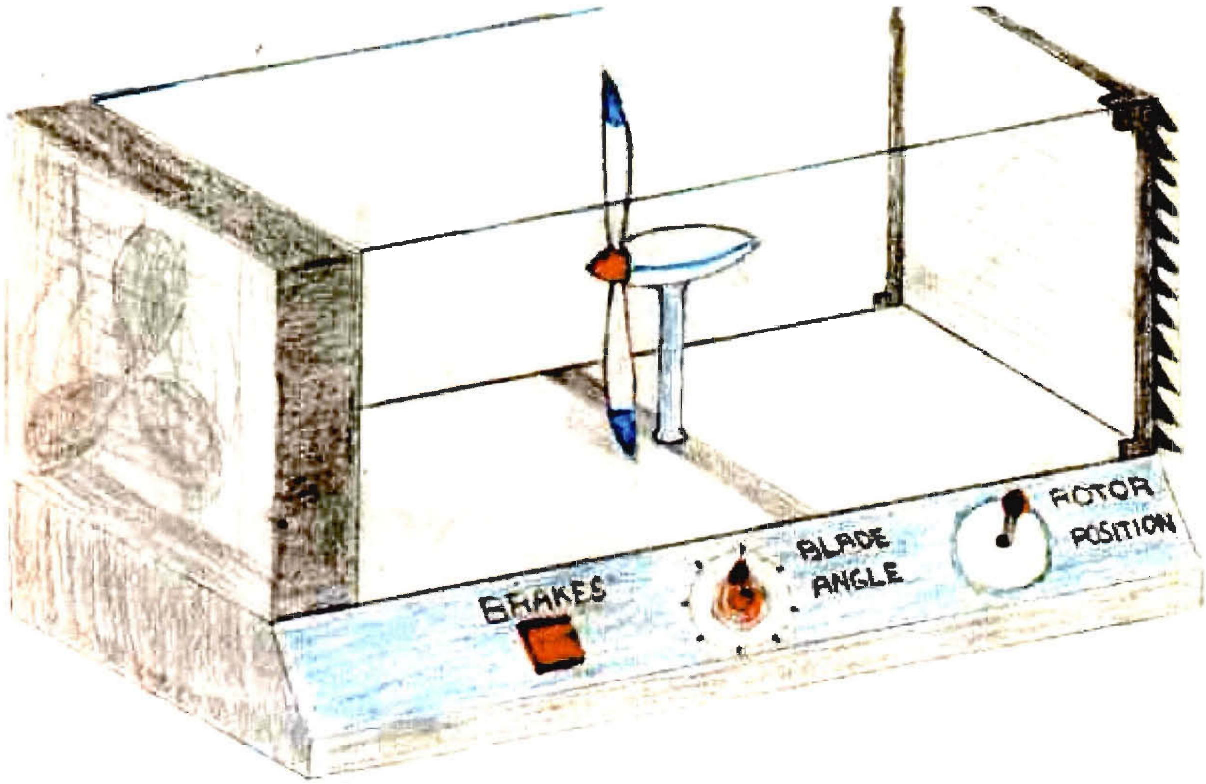
User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Use the dials and buttons to create the highest amount of kilowatts produced or homes lit up.

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)

Sketch overleaf: (***Idea as currently visualised, with annotations***)



Small commercial wind turbine mounted inside a Plexiglas wind tunnel. Three controls actuate the propeller-tip brakes, blade angle, and rotor position.

Exhibit Template Sheet

Project Title: Wind Table

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

Wind as a source of energy and how it affects us.

Subject Matter: (*What must be in the exhibit?*)

Explaining the importance of the location of wind turbines to maximise their efficiency while keeping aesthetics in mind.

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

Know what a wind turbine is. (to be explained elsewhere in gallery)

Cognitive Outcomes: (*Perception, memory, thinking*)

The placement of the turbines and their alignment to the wind affects the efficiency.

Affective Outcomes: (*Emotions, feelings, impressions*)

Excitement over generating electricity and trying to obtain the high score

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Wind Table Date: 2000-02-21
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Idea

Description:

A table contains a model of a piece of land with varying landscape and wind blowing across it. There are slots all over the table and the visitor can press a button to have a turbine pop up. Placing the turbines in an optimal area produces electricity and a light bulb will light up.

Number of users/observers:

1-4 users

Number of functional Inputs/Outputs: ***(How complex is the activity?)***
10 inputs (# of turbines that can be popped up at once)
3 outputs (light bulb, Kwatt scale and high score sign)

Duration of activity:

5 minute

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Press a button to produce turbines.

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, co-op/social interaction, physical control

Attraction: (*How will it attract people and how will it keep them there?*)

Large light bulb, potential to beat high score

User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Press the buttons to place the wind turbines to produce electricity

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Spatial

Technical issues: (Any technical requirements that are currently known)

Sketch overleaf: (***Idea as currently visualised, with annotations***)

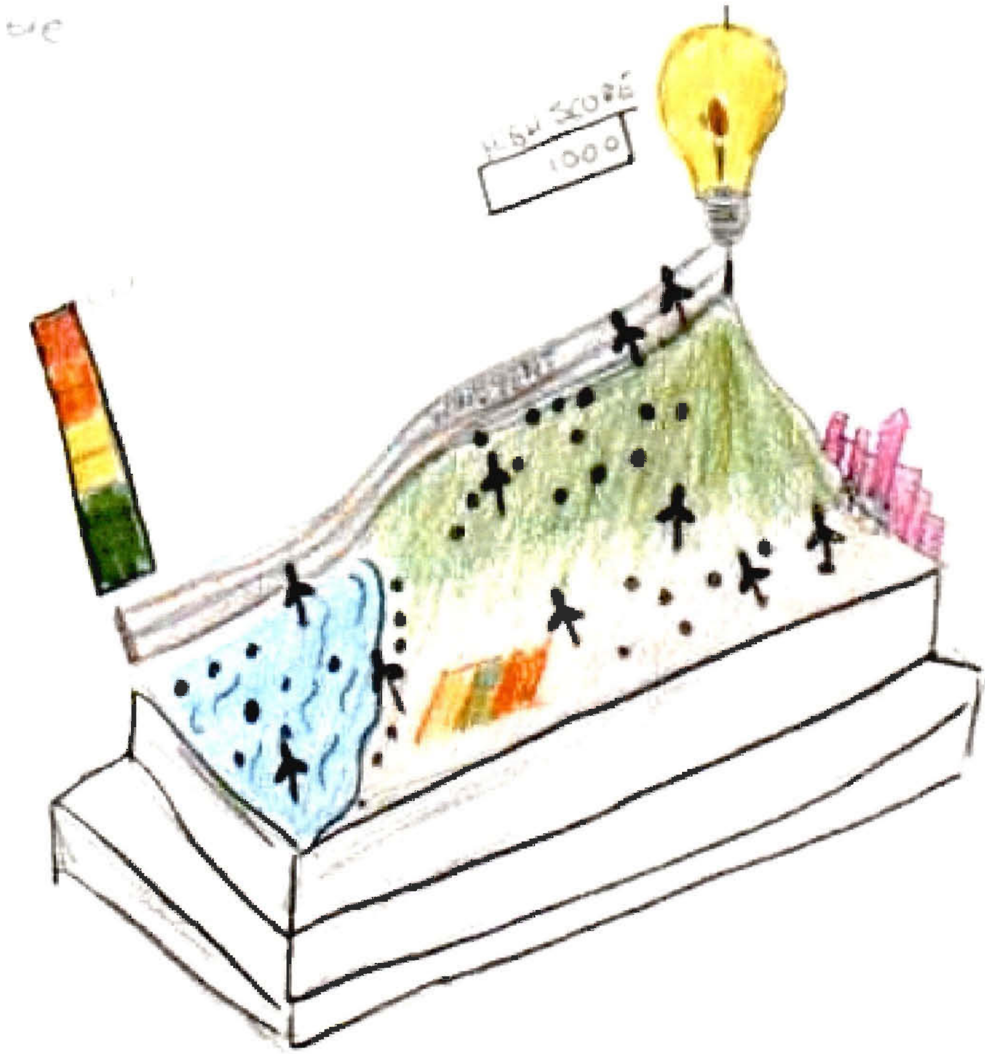


Exhibit Template Sheet

Project Title: Where in the World

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

Wind as a source of energy around the world

Subject Matter: (*What must be in the exhibit?*)

Show how wind is being used around the world and show where it is being used.

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

understanding of a globe

Cognitive Outcomes: (*Perception, memory, thinking*)

Discover locations of wind farms and understand the amount of wind in various countries

Affective Outcomes: (*Emotions, feelings, impressions*)

Excited to know how different countries use wind as a source of energy

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Where in the World
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Date: 2000-02-21

Idea

Description:

A large globe (approximately 5 feet including base) will contain buttons in the countries that have wind farms. Upon pressing a button a monitor that is on the globe will show that particular wind farm and give an explanation of it and how it is used.

Number of users/observers:

3 users / 4-5 observers

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

inputs is not determined 3 outputs

Duration of activity:

15 seconds per country

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Press buttons

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, physical control

Attraction: (*How will it attract people and how will it keep them there?*)

Television monitor, interaction, large bright globe

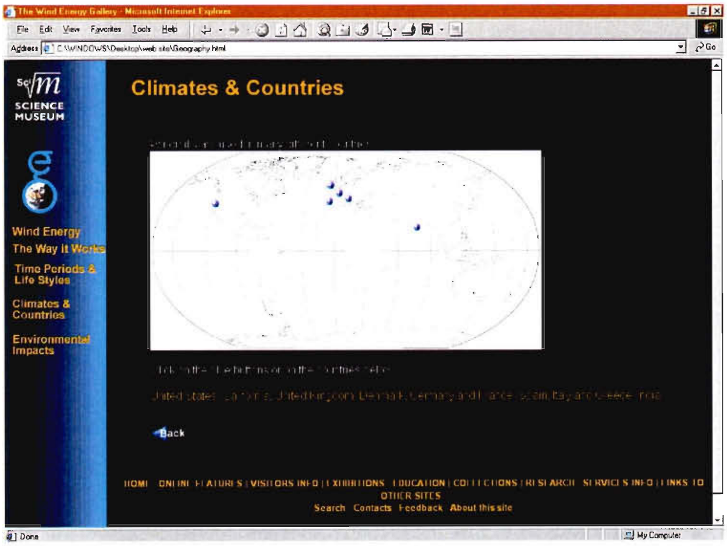
User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Press a button in any country on the globe and watch a video clip of that wind farm and see how much wind is produced.

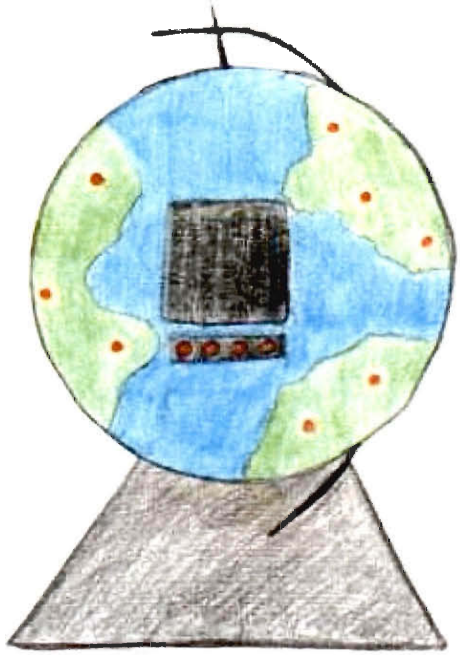
Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)

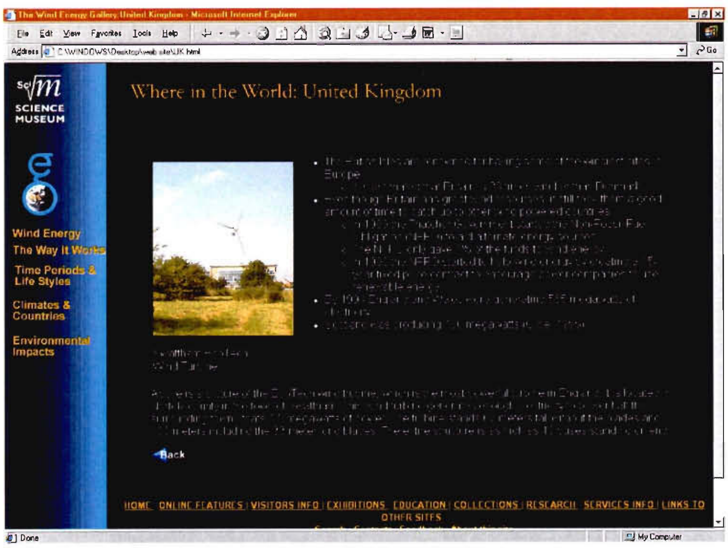
Sketch overleaf: (***Idea as currently visualised, with annotations***)



Virtual exhibit main where in the world page



Where in the World physical exhibit



Virtual exhibit example of a country

Exhibit Template Sheet

Project Title: Wind Power Matching Game

Exhibition/Area: Energy Gallery   Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

To understand how wind was used in different locations and time periods and what the different wind machines did.

Subject Matter: (*What must be in the exhibit?*)

Being able to associate a wind machine with a time period.

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

Being able to recognise different time periods

Cognitive Outcomes: (*Perception, memory, thinking*)

To realise how wind machines have affected peoples live throughout time.

Affective Outcomes: (*Emotions, feelings, impressions*)

Satisfaction in being able to match the wind machines with their appropriate time period.

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Wind Power Matching Game — Date: 2000-02-21
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Idea

Description:

There are 3 sets of triangular devices with pictures on each side, one with the wind machine and the other a time period. The visitor must match them and then a video clip will be displayed w/ a description of the wind machine and when and why it was used.

Number of users/observers:

3 user

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

3 inputs / 3 outputs

Duration of activity:

1 minute

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Turn blocks

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, physical control

Attraction: (*How will it attract people and how will it keep them there?*)

The video clips

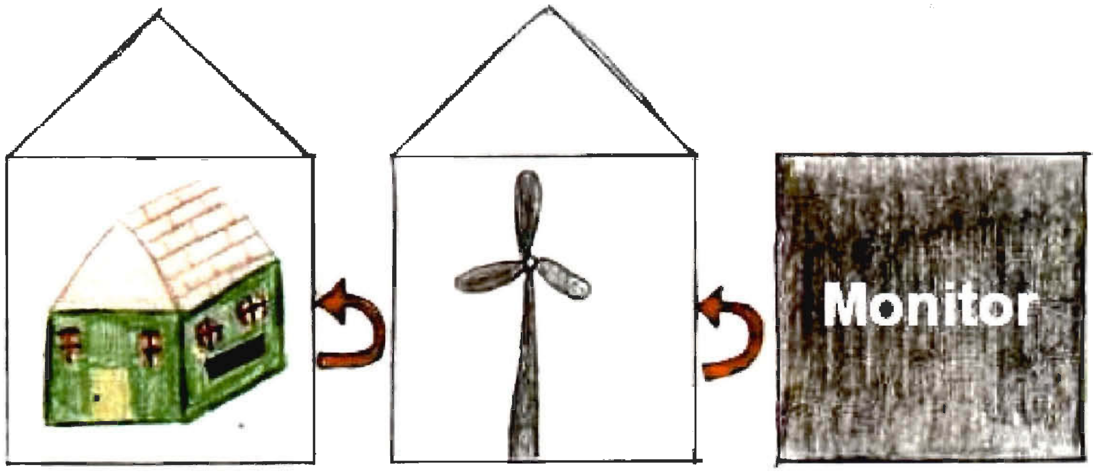
User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Turn the blocks to correctly match up a time period with a wind machine

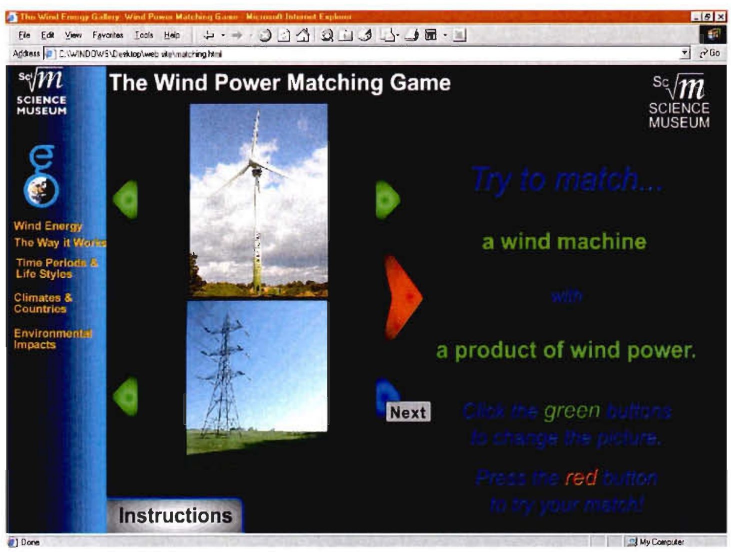
Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)

Sketch overleaf: (***Idea as currently visualised, with annotations***)



The two objects on the left are the rotating blocks that display the images to be matched. The object on the right is the television monitor that displays further information about the wind machine when the user makes a correct match.



Virtual exhibit matching game

Exhibit Template Sheet

Project Title: Hearing the Wind

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

How wind affects us

Subject Matter: (*What must be in the exhibit?*)

Explaining and demonstrating what windmills and wind turbines sound like in comparison to other sounds.

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

none

Cognitive Outcomes: (*Perception, memory, thinking*)

Windmills and wind turbines produce sound

Affective Outcomes: (*Emotions, feelings, impressions*)

An understanding of how loud a wind turbine

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Hearing the Wind
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Date: 2000-02-21

Idea

Description:

The visitor can put his/her head between two speakers to hear different sounds depending upon the button he/she chooses and a monitor will also display an image of the source of the sound.

Number of users/observers:

1 user per sound station

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

5 inputs / 1 output

Duration of activity:

1 minute

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Choose sound by pressing button. Listen to headphones.

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, sensation/other senses

Attraction: (*How will it attract people and how will it keep them there?*)

noise

User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

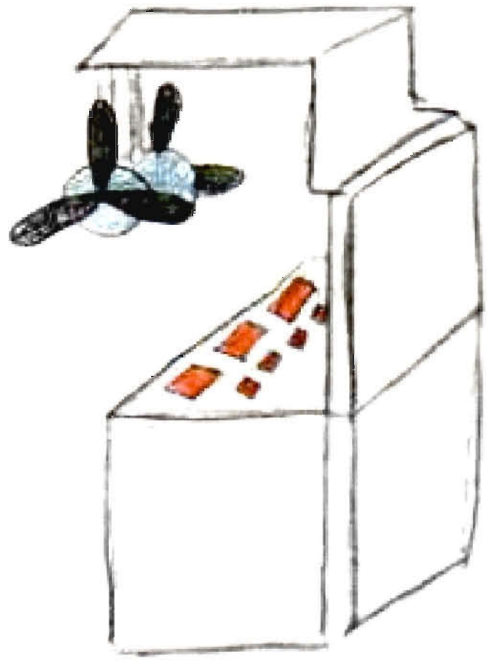
Press a button to hear what a variety of sounds sound like.

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Musical (sound)

Technical issues: (Any technical requirements that are currently known)

Sketch overleaf: (***Idea as currently visualised, with annotations***)



This is one sound station shown from the back-right corner. The earphones can be seen hanging down in front of the control panel. The view screen is located on the panel above the buttons.

Exhibit Template Sheet

Project Title: Power of Wind Entrance Way

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

How wind energy is used

Subject Matter: (*What must be in the exhibit?*)

Shows the change in wind technology over time

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

none

Cognitive Outcomes: (*Perception, memory, thinking*)

There are different types of wind machines

Affective Outcomes: (*Emotions, feelings, impressions*)

Excited about learning more about wind energy

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Idea

Description:

An entranceway consisting of a windmill and a wind turbine connected by an arch reading "The Power of Wind." As visitors walk through the entrance a breeze will blow on them.

Number of users/observers:

Objects included: (***include multimimsy information***)

Windmill model, wind turbine model

Location of object as of date:

Entrance

Description of object:

Attraction: (***Why will it attract people?***)

Large models, breeze

Sketch overleaf: (***Idea as currently visualised, with annotations***)

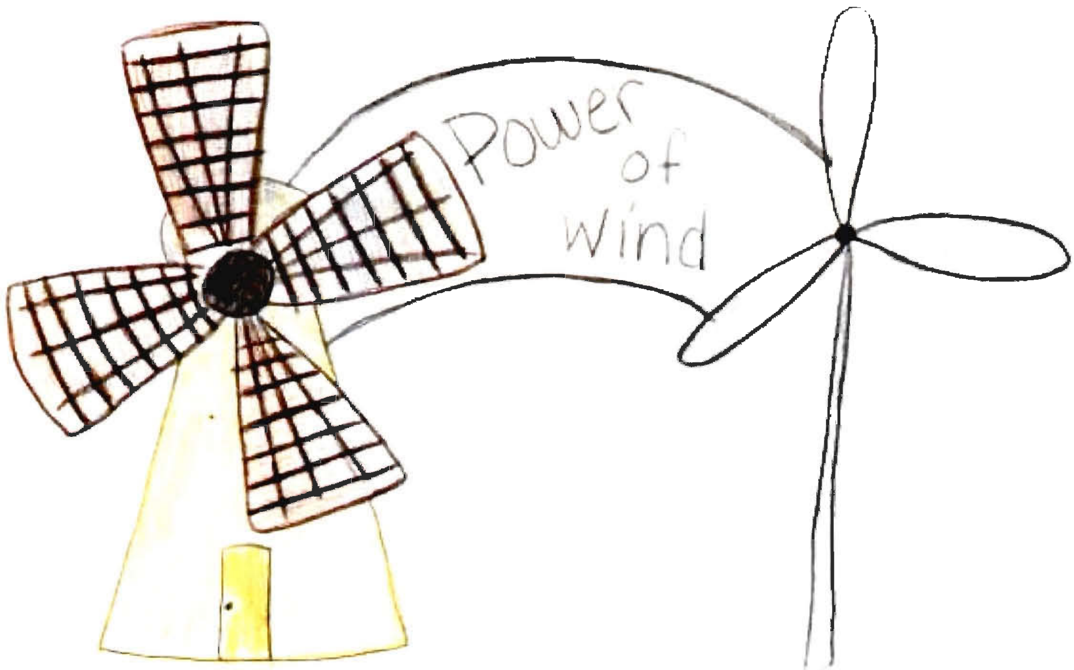


Exhibit Template Sheet

Project Title: Inner Workings

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

An understanding of how a wind turbine works

Subject Matter: (*What must be in the exhibit?*)

Explaining and demonstrating what the insides of a turbine look like

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

The definition of a wind turbine

Cognitive Outcomes: (*Perception, memory, thinking*)

What makes up a wind turbine

Affective Outcomes: (*Emotions, feelings, impressions*)

An understanding of what the insides of wind turbine looks like

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Idea

Description:

The user can put together a puzzle of a wind turbine and read about how it is made. Then he can test it and if it was put together properly the turbine will work.

Number of users/observers:

1 user / 3 observers

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

5 inputs / 1 output

Duration of activity:

2 minutes

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Ability to put puzzle together

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice, physical control

Attraction: (*How will it attract people and how will it keep them there?*)

Can see what you put together work

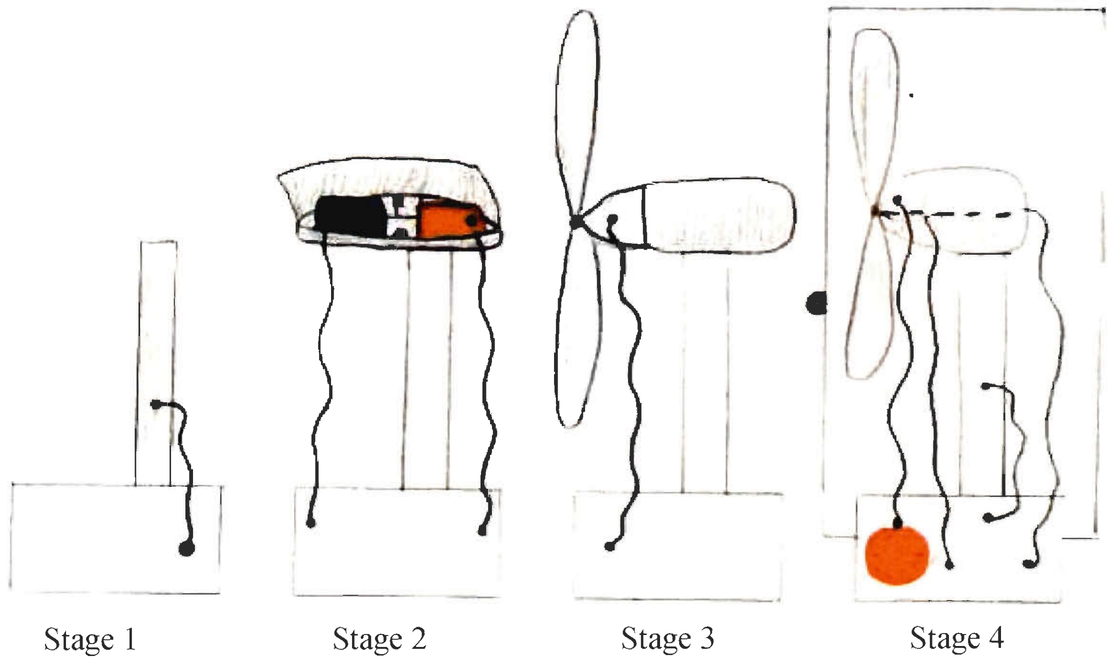
User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Build the turbine and if it is correct it will work

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)

Sketch overleaf: (*Idea as currently visualised, with annotations*)



Stage 1: Visitors place pole
Stage 2: Visitors place pod, gearbox, and generator
Stage 3: Visitors place cone and turbine blades
Stage 4: Visitors close door and press button to make turbine function

Exhibit Template Sheet

Project Title: Good Vs Bad

Exhibition/Area: Energy Gallery   Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

How using wind energy as a source of power affects the town

Subject Matter: (*What must be in the exhibit?*)

To understand the positive and negative aspects of using wind energy

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

The definition of wind energy

Cognitive Outcomes: (*Perception, memory, thinking*)

The factors concerned when implementing wind turbines

Affective Outcomes: (*Emotions, feelings, impressions*)

A sense of accomplishment in designing a town that effectively uses wind turbines

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Working Turbine | Date: 2000-02-21
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Idea

Description:

The user is allowed to build turbines wherever he wants, but he will encounter various problems such as unhappy residents, insufficient wind, and a lack of money.

Number of users/observers:

1 user

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

N/A

Duration of activity:

30 minutes

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Use of computer

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Choice

Attraction: (*How will it attract people and how will it keep them there?*)

The ability to design a town with wind power.

User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Choose where you would build turbines but be aware of the problems it may cause.

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)

Exhibit Template Sheet

Project Title: Pinwheel Creation Table

Exhibition/Area: Energy Gallery Date: 2000-02-21

Developer: Laura Domey, Wendy Kogel, Benjamin Newton

(NB. Multi-levelled exhibits *may* require templates for each level, e.g. as a group and individually)

Proposed Exhibit Title/Number:

Content

Higher Level Content: (*What is the wider exhibition/area content that the exhibit must fit into?*)

To understand how wind turns the blades of a wind machine

Subject Matter: (*What must be in the exhibit?*)

A better understanding of windmills and wind turbines work upon designing a pinwheel

Target Audiences: (*Who is it for? NB. Groups not listed will not be catered for*)

Key stages 2 and 3

(*Include* prior knowledge assumed)

Cognitive Outcomes: (*Perception, memory, thinking*)

Wind powers windmills and wind turbines

Affective Outcomes: (*Emotions, feelings, impressions*)

Happy to make their own model

Conative Outcomes: (*Will, intentionality, planning*)

Behavioural Outcomes: (*Movement, activities, habits*)

Project Title: Pinwheel Creation Table
Exhibition/Area: Energy Gallery
Developer: Domey, Kogel, Newton
Proposed Exhibit Title/Number:

Date: 2000-02-21

Idea

Description:

The user can access instructions to design their own pinwheel and read information about it.

Number of users/observers:

N/A

Number of functional Inputs/Outputs: ***(How complex is the activity?)***

N/A

Duration of activity:

10 minutes

Interaction Characteristics: (*Demonstrations and/or Tasks*)

Making a pinwheel

Motivation: (*Are any of the following 'Design Constructs' used: Surprise, Choice, Co-operation/social interaction, Sensation/other senses, Physical control, Self/social image*)

Attraction: (*How will it attract people and how will it keep them there?*)

Physically make and design something

User instructions: (*A developmental tool: How would you tell someone to use the exhibit, as currently planned*)

Download information to make your own pinwheel

Supported Learning Styles: (*Linguistic, Bodily-kinaesthetic, Logical-mathematical, Interpersonal, Spatial, Musical*)

Technical issues: (Any technical requirements that are currently known)