Project Number: JSD-LD18 - 41

A WEB-BASED RENEWABLE ENERGY EXHIBIT FOR THE NATIONAL MUSEUM OF SCIENCE AND INDUSTRY, LONDON

An Interactive Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfilment of the requirements for the

Degree of Bachelor Science

By

Elizabeth Hart

Joseph Knuble

David Tolmie

Exhibit Location: http://www.wpi.edu/~dtolms/energy.html

1. Renewable Energy
2. London
3. Science Museum

Approved:
Date: April 27th, 2001

Professor James S. Demetry

Professor Ruth L Smith

Abstract

The Museum of Science in London feels the visitors to the museum have an incomplete understanding of the power potential of renewable energy systems. We designed an interactive web-site which clearly and concisely simulated the output potential of wind and solar energy systems which may soon be installed on the museum roof. Observation and feedback surveys enabled the Museum to asses relative interest between different renewable energy systems and exhibit formats for use in future exhibit decisions.

Executive Summary

A world crisis looms as consumption of energy sources increases while the supply diminishes. Exploiting the vast resources of clean and renewable energy could help alleviate this problem. The National Museum of Science and Industry in London hopes to showcase this pressing fact through exhibits incorporated into their Energy Gallery. The Museum may soon install various renewable energy systems on their roof and use these technologies both as learning tools and sources of useful electricity. However, an effective method to portray the potential of such systems to the public needed to be developed. In turn, our team has created an interactive web-based exhibit displaying the potential usage of the renewable energy systems which will inhabit the roof. The goal of the exhibit was to educate the younger visitors of Museum about the benefits and performance of such technologies in a clear and intriguing manner.

The technological focus of the project was defined as the exploitation of wind and solar energy. Intense background research was performed in both of these fields to uncover the capabilities and characteristics of the systems which harness this energy. Photovoltaic solar arrays and wind turbines were selected as the technologies to be showcased in our exhibit. Additional research was performed in the area of museum exhibit design through textual sources, interviews, and visits to other science museums.

Key factual points were defined which had to be covered in the exhibit in order to give the public a proper understanding of the renewable energy system. Subsequently, methods to clearly communicate this information were developed which led to the design and creation of the web exhibit. To confirm an exhibit had been produced which satisfied several predetermined conditions, interviews were first

conducted with museum staff to find their opinions and suggested improvements for the site. Necessary changes were considered and made before an evaluative survey was performed with Museum visitors. The survey was tailored to determine if the information was well understood by the patrons, and which forms of information presentation they most preferred.

Finding information regarding what portion of the exhibit patrons felt is most interesting will be important data for the Museum when they design larger exhibits related to the roof systems. Data analysis has been performed regarding what kinds of exhibit formats are most appealing to the public within this field. Additionally, should the Museum decide to showcase only one technology, the data presented in this project will provide an initial suggestion as to which energy source should be pursued.

This project has resulted in a unique web exhibit which tackles the complicated topics of renewable power systems to allow children to gain a firm grasp of the information presented. The exhibit will exist as a valuable tool for the Museum of Science to further their goal of educating the public in the area of energy production. Finally, information gathered by this IQP team will be used to enhance the calibre of future exhibits dealing with the future of the world's energy supply.

Authorship Page

Abstract

Author: Elizabeth Hart, Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Executive Summary

Author: Joseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

1. INTRODUCTION

Author: Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2. BACKGROUND RESEARCH

2.1 Renewable Energy

Author: David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.2 Solar Energy

Author: Elizabeth Hart
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.3 Wind Energy

Author: Joeseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.4 Museum and Exhibit Design

Author: David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.5 Observational Data

Author: Elizabeth Hart, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.6 Surveying

Author: Joseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.7 Interviews

Author: David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

2.8 National Curriculum in England

Author: Elizabeth Hart
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix B – Summarised Notes from and Interview with James Hanlan
Author: Elizabeth Hart
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix C – Summarised Notes from an Interview with Matthew Straumpf
Author: Joseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix D – Preliminary Evaluation Questionnaire for Museum Staff
Author: Elizabeth Hart, Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix E - Summarised Notes from Interviews with Museum Staff
Author: Elizabeth Hart, Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix F – Observation Sheet and Feedback Survey Questions
Author: Elizabeth Hart, Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix G – Design Process: Creative and Content Decisions
Author: Joseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix H – Java Weather Monitoring Program
Author: Joseph Knuble
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Appendix I – Site Map
Author: David Tolmie
Editor: Elizabeth Hart, Joseph Knubel, David Tolmie

Appendix J – Web Site Screen Shots
Author: David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Web-site

Content
Author: Elizabeth Hart, Joseph Knuble, David Tolmie
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Graphics
Author: Joseph Knuble, David Tolmie,
Editor: Elizabeth Hart, Joseph Knuble, David Tolmie

Java Author: Joseph Knuble

HTML Author: Joseph Knuble

Flash Author: Joseph Knuble, David Tolmie

Table of Contents

List of Figures

1. INTRODUCTION

What is a proper and effective method by which to educate patrons of the National Museum of Science and Industry about the potentials of the renewable energy systems the museum showcases? How can the information be presented in a clear and informative manner while allowing the Museum to evaluate how individuals explore the material presented? A solution to such problems will not only enhance the calibre of the Museum, but also provide valuable education to the people of the UK and elsewhere.

Interactive web-based exhibits have proven quite useful for conveying large amounts of information in a manner easy to interact with and explore individually. Additionally, such exhibits can be designed relatively quickly and offer greater opportunities to scrutinise the different topics people are interested in. The point-and-click interface of web-sites allows people to quickly access data that fascinates them and bypass that which does not. Photovoltaic arrays and wind turbine energy systems were the essential focus of the exhibit we developed, as they are renewable energy sources the Museum may install for an exhibition. A station may in the future be constructed on the roof of the Museum where different operating renewable energy systems will be located. The web exhibit correlates the potential outputs of these roof exhibits into interactive programs for people to experiment with on their own. It is intended that this exhibit should enhance the knowledge of the public regarding the power generation of each of the respective technologies.

Besides the mentioned benefits to the Science Museum, the visitors are able to gain the true intended benefits of the system. An essential component to understanding renewable energy is having a real-world understanding of the amount of power it can produce. The Science Museum now has means to present throughout the Museum the possible technologies that could inhabit the roof.

In order to meet the specifications of the web exhibit, a clear outline of the content of the site was defined. This developed from the objectives of the site and then centred on the outputs and energy potential of the different systems. Target age groups were also taken into consideration as well as educational background. The site's effectiveness was evaluated through observations and a follow-up questionnaire, which the results from could be analysed. This information was synthesised in a manner to allow a conclusion on which forms of interaction with potential roof exhibits the public is most interested in.

The Interactive Qualifying Project is designed to enable students to further understand how their careers as students and professionals impact the social structures they are a part of. This project explored a method for using a technology for more than simple power generation. The photovoltaic array and wind turbine will be used as instruments for education. Renewable energy is an important focus for this and future generations, and the more we understand its benefits and uses, the more we can apply it to our world's energy demands.

2. BACKGROUND RESEARCH

The following information was gathered from literature and reviewed to provide valuable information that would be needed before starting this project. It was felt vital to gain the knowledge and understanding of these topics in order to be able to carry out the project and obtain conclusive, valuable and useful results.

Before researching the different types of renewable energy systems, it was necessary to find what the term renewable energy referred to. Then it was possible to investigate solar and wind energy. With these different types of information found, it was possible to proceed to look at what characteristics made up an effective exhibit and how to productively evaluate its quality.

2.1 Renewable Energy

The UK Renewable Energy Advisory Group (REAG) defines renewable energy as the term used to cover those energy flows that occur naturally and repeatedly in the environment and can be harnessed for human benefit (Boyle, 1996, p.27). The ultimate source of most of this energy includes the sun, gravity and the earth's rotation.

Implementing or resorting to a renewable energy system as a primary power supply is very beneficial over standard fossil and nuclear fuels. Compared to the use of fossil and nuclear fuel, using renewable energy sources to replace the traditional systems would reduce the negative environmental impact associated with fossil and nuclear fuels. Solar energy along with wind and water energy is derived from solar radiation and can be used to generate electricity or heat. In using renewable energy sources, one does not have to worry about the problem of reserve energy running out, which is a problem when using fossil and nuclear fuels. Finally, renewable energy systems can be deployed on a more individual basis without the worry of a central power source suddenly being disabled. The museum is hoping to implement upon the roof an energy system consisting of a photovoltaic array and a small wind turbine. These two sources are explained below.

2.2 Solar Energy

The sun has always been a major source of heat and energy. In recent years, society has been looking into ways to capture and use this valuable renewable energy resource. The European Union (EU) also is working on raising public awareness of the need to reduce the emissions of greenhouse gases, and to do this by using renewable energy sources (Oil & Gas Journal, 1999, p.54).

Thermal and electrical compose the two types of solar energy,. Solar concentrators produce thermal energy while photovoltaic devices produce energy in electrical form. Both forms are vital in maximising the potential for solar energy. Recognising the importance of renewable energy, London Transport has started the development of projects that will utilise solar power in the London Underground system (Hibbert, 1999, p.38).

2.2.1 Types of Solar Energy

There are various means of capturing solar energy. Concentrating systems are typically on a larger scale, powering steam turbines. Solar water heaters are smaller, which can practically be used in residential applications. Photovoltaic arrays, while practical for use in homes, are still an expensive investment and therefore more feasible for the larger roof surfaces associated with industrial and commercial structures. It is important that the public gain an awareness and understanding of applications such as these.

2.2.2 Photovoltaic Devices

Photovoltaic (PV) devices utilise solar energy by directly converting light into electricity through a semi-conducting material (Ginsburg, 2000, p.138). One of the most common materials used in PV devices is silicon. Silicon is considered a semiconductor because it undergoes a process know as doping. Boron and phosphorous are most frequently used as doping agents. The addition of boron leaves the silicon with a shortage of free electrons. This is a p (positive)-type semiconductor. An excess of free electrons occurs when silicon is doped with phosphorous, an n (negative)-type semiconductor (Boyle, 1996, p.97). Forming a p-n junction, which occurs when these two opposing cells are connected, creates an electric field. Individual cells brought together form a module, and groups of modules are brought together in an array. Shown below is a generic photovoltaic cell.

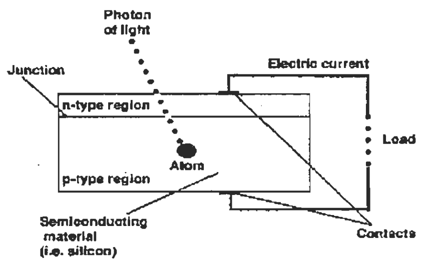


Figure 1 – Photovoltaic Cell

PV cells function only when the sun is shining on them. They therefore cannot be used for applications in which a steady source of electric supply is required (Kren, 1999, p.46). Current research is being done into improving the application of thin film technology. Thin film cells are more economical than single crystal cells but are not used widely commercially because of their low conversion efficiency. However, recently there have been some technological improvements. In Golden, Colorado, at the Department of Energy (DOE) National Research Energy Laboratory (NREL), a newly developed model had a conversion efficiency of twelve percent under laboratory conditions, 11.4% under realistic ones. This beats the current efficiency by fifty percent. The cells tested were production models, not prototypes, so they show how the cells will react when used in the actual environment. They held up well to the elements, and it should be inexpensive to produce the needed quantity.

Current markets for PV devices include consumer products such as solar calculators and watches and account for one third of the PV market (Baird, 1993, p.4). The largest remains in remote power applications where there is inconvenient or too expensive to use conventional grid supplies. The third major market is utility generation - supplying electricity to electrical transmission grids. This is accomplished by an array of PV devices that act as a traditional large power source.

Silicon cells have a potential of 0.6 volts direct current (DC). With thirty-two to thirty-six cells in a solar module, the total potential under industry standard conditions is 12 volts DC and 75 Watts.

2.2.3 Storage of Solar Energy

There are ranges of possibilities for solar heating storage systems (Boyle, 1996, p.56). Two kinds of systems blend into each other, that of 'active' heating and 'passive' heating. Starting with the rising oil prices in 1973, there was a surge in the use of solar energy systems. In the UK there have been 40,000 solar heaters installed. Electricity gained from PV cells can be stored in a battery for use in the future.

A solar heater is a tank of water placed in the path of solar radiation, such as behind a window (Boyle, 1996, p.58). Solar heaters can be used to preheat water used for residential applications. A variety of active heating solar collectors include unglazed panels, flat plate water collectors, flat plate air collectors, evacuated tube collectors, line focus collectors and point focus collectors (Boyle, 1996, p.59). These devices are usually roof mounted and once implemented are difficult to reach for maintenance and repair. Since panels do not need to be installed at particular levels to achieve acceptable performance this means that an increased number of builders can utilise this technology.

Essentially any building with windows it to some extent passively heated (Boyle, 1996, p. 63). The Wallasey School building in Cheshire, built in 1961, has all the characteristics required for passive solar heating. These include a large area of south facing windows that capture the sunlight, thermally heavyweight construction, such as concrete or brick that stores thermal energy through the day into the night, and the outside of the structure is thickly insulated to retain the heat (Boyle, 1996, p.64). The oil fired heating system originally installed was found to be unnecessary and has since been removed; heating of the building now relies entirely upon a combination of heat from solar energy, fluorescent lights and body heat from the students.

2.2.4 Current Uses of Solar Energy

Electricity from PV cells can be used to charge a lead-acid battery, which can be then used in further applications (Boyle, 1996, p.115). PV applications are practical systems for developing countries. In most of these countries, electricity grids are most often non-existent. Also, traditional forms of energy are too expensive. Water pumping, irrigation for drinking water, PV refrigeration systems, energy for lights, radios, televisions and street lighting are all currently power by PVs.

2.3 Wind Energy

Wind energy has been used as a source of renewable energy for thousands of years (Boyle, 1996, p.267). Recent technological developments in materials processing, manufacturing and energy conversion have made harnessing wind energy a commercially feasible activity in contemporary society. The breadth of the energy system is great, and a full understanding of it requires investigation into its mechanical technology, energy production, and related limitations. Such a background is necessary to investigate the potential for an appropriate implementation of it within the Science Museum.

2.3.1 Technical Background

The most common form of commercial wind turbines is that of the horizontal axis wind turbine (HAWT) (Boyle, 1996, p.268). The HAWT is typically composed of one, two, or three blades mounted in a propeller-like fashion, which faces directly into the wind. When struck by a gust of wind, the shape of the blades causes a force to push them in such a way that they rotate about an axle attached to a generator. This is the essential technical basis behind the process of converting wind energy into electrical energy. Figure 2 shows an example of a HAWT turbine.

Figure 2 - HAWT

The HAWT is categorised into groups of small scale, medium scale, and large scale based on the rated power they produce (Boyle, 1996, p.268). Small-scale turbines produce up to 100 kilowatts (kW), medium scale produce between 100kW and 700kW, and large-scale turbines produce ranges above 700kW. This naming standard is not universal yet is a generally accepted for use in turbine vocabulary.

A second type of turbine design incorporates an axle and blades that rotate in a cylindrical plane perpendicular to the ground (Boyle, 1996, p.269). At the ends of this axle are tall blades that perform the function of wind capturing. This system is referred to as the Vertical Axis Wind Turbine (VAWT). Figure 3 shows an example of such a turbine.

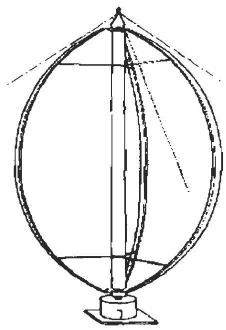


Figure 3 – VAWT

Unlike the HAWT which must rotate to face the wind through a process called yawing, the VAWT has the advantage that its operation is not dependent on the direction of the wind;. Additionally, the VAWT system places relatively little stress on its support structure. However, the blades for the VAWT have an eggbeater like curvature to them and hence are difficult to manufacture and transport. The end result is that VAWTs are not economically competitive with HAWTs at this time.

Turbines incorporate various characteristics that are used to describe them (Boyle, 1996, p.269). The cut-in speed of a turbine refers to the minimum wind speed necessary to rotate the blades. Wind turbines, although quite sturdy, have operational limits to avoid extreme vibration and other hazards that can result from operating in wind currents that are too strong for it to handle. The cut-off speed refers to the maximum wind speed the turbine can safely operate at before internal breaks shut down the rotation of the blades. The rated power for a turbine refers to the maximum amount of power it can produce.

Understanding the underlying physics behind turbine operation is of practical importance for understanding the mechanical system as a whole (Freris, 1990, p.66). The blades are essentially aerofoils - the same wing shapes incorporated in airplanes. Drag force refers to how much force is applied to an object when it is placed in a wind stream. Obviously, the greater the area of the surface exposed to the wind, the greater the force the wind will exert upon it. Aerofoils, like any object in a wind stream, are subject to drag forces. This force must be minimised in blade design through a combination of material properties and aerofoil design for it tends to push the blades in the opposite direction of lift. Lift is a force perpendicular to the direction of the wind, which pushes the wing up. The rounded shape of the aerofoil causes air moving over the top to move faster than that of the bottom. Faster moving air induces a lower pressure on an object than slower moving air. The net result is the object is pushed in the direction of the rounded top. This is the force which propels the turbine in a direction, which ultimately generates electricity. In order for HAWT direction to proceed, the yawing mechanism constantly realigns the blade plane into the direction of the wind. The performance of the wind turbine is dependent on the number of blades, their respective weight and shapes. The shapes have many complex considerations made in order to improve lift and reduce drag. The weight of each blade and the number of blades incorporated must also be balanced for optimum rotation power and stability.

2.3.3 Power Generation

The amount of power generated by a turbine is directly related to the wind speed in the area and is often summarised in associated wind speed-power curve charts (Boyle, 1996, p. 292). A general formula for calculating the annual power output for a turbine can be found via:

kW-hours of electricity = FV^3AT

Where F = 2.5 and is a factor for the adjustment of turbines typically operating for 90% of the year and other energy losses. V is the site's average annual wind speed in meters per second. A is the swept area of the turbine in meters. This is the area of the circle, which the edges of the rotating turbine blades form. And T is the number of turbines in use, which is useful for wind farm calculations (Boyle, 1996, p. 292).

The average velocity can be obtained by performing measurements or by investigating historic records of wind patterns in the desired area (Cole, 1995, p.180). The European Wind Atlas contains information about mean wind speeds all over Europe at altitudes of 50m. It must be realised that the annual power calculation represents only a mean and can vary greatly throughout the year from little or no wind to great gusts. Wind power is highly variable in this respect. For reliable power supplies, diesel backup generators are suggested along with a battery power storage system to store surplus power from the turbine. With an appropriate interface, it is also possible to connect the wind system so it is a part of the conventional energy grid, supplying a portion of the power needed, reducing the total amount of fossil fuels used.

2.4 Museum and Exhibit Design

Designing an effective exhibit means taking into account many considerations. Exhibit size as well as the amount and presentation of information are important qualities that need to be carefully thought out before constructing an exhibit. Every exhibit caters to a specific viewing audience which is usually designated by age. Knowing the curriculum of the target audience will not only structure the information presented, but also the presentation itself. Exhibits are not simply found inside a museum. With technology such as computers and the world-wide-web, exhibits are now entering cyberspace where users can gain access from the comforts of their own home. These exhibits require additional special considerations that must be taken into account in order for them to be effective.

2.4.1 Purpose of Exhibits

One characteristic of museum exhibits that is most important is that exhibits should be able to facilitate an interaction between visitors and actual information (Belcher, 1991, p.38). The most important function of museum exhibitions is to bring the visitor closer to the physical exhibit. An exhibition, which is a collection of exhibits, is a space where the visitor is able to wander around freely and at his or her own pace. Allowing the visitor to wander around the exhibition allows him or her to spend time at the exhibits that interest them and pass by the ones they dislike.

The way in which a museum accomplishes its goals is through exhibits (Lewis, 1976, p.113). An exhibit is put into place in order for people to be able to learn. Having a display gives the visitor more physically tangible access to information. Being able to see an actual exhibit may give clarity to any confusions or misconceptions the visitor might have had about the idea prior to the visit. There are several different approaches a designer can take in order to convey this idea.

An exhibit will incorporate a wide variety of methods when appealing to the senses of the public (Belcher, 1991, p.38). Some of these methods include interactive displays, vibrant scenes, graphics and animation. Belcher states that it is most effective to reach a wide audience by using a combination of methods. Effective uses of these methods include attracting attention, jumpstarting trains of thought, resolving feelings on an issue, providing the viewer with information or a variety of outcomes (Lewis, 1976, p.120).

Science education benefits from exhibits as they can stimulate the interest of the public in scientific issues, while also informing viewers how science affects their everyday lives (Belcher, 1991, p.39). This is done by stimulating multiple senses of the visitor.

2.4.2 Exhibit Planning

Museum exhibits are a means of communication. To plan out a successful exhibit, the person planning should be familiar with five aspects in order to communicate the ideas in a correct manner (Neal, 1973, p.21):

- The idea or story to be told
- The objects with which to tell it
- The area or space to be devoted to the story (size, dimension, shape)
- An awareness of the audience it is to reach
- And knowledge of available cases and panels, of building materials and design techniques with which to present the story

There are several stages that are used to create a typical museum display. The basic stages in the design process of an exhibit are as follows (Belcher, 1991, p.80):

- Awareness of the need
- Preliminary consideration of proposal
- Feasibility study
- Consideration of feasibility study
- Further research
- Formulating the communication

- Conservation
- Preparation of the brief
- Exhibition design
- Formal approval
- Finalising the proposal
- Tendering
- Production
- Opening, on-going monitoring and maintenance.

With regard to our original objectives, our project will focus on all of the above steps. Initial design considerations, implementing the design and finally evaluating its quality will all be covered in this IQP.

In order to achieve a successful design solution, one must start with a brief, which is a systematic and methodical approach to the problem (Belcher, 1991. p.89). The purpose of the brief should be to define the exhibition problem so the designer can formulate a solution. The brief also allows the people working on the project to clarify their ideas and commit themselves to making firm decisions on things that arise in their project.

2.4.3 Exhibition Effectiveness

Many believe the word exhibit refers to something that is visible behind glass. The effectiveness of an exhibit can be improved dramatically by engaging as many senses of the visitor as possible (Lewis, 1976, p.118). Museum exhibits communicate through three main aspects. The physical structure of the exhibit, the message, which is the whole concept of what the exhibit is trying to communicate, and the visitor's interpretation and reaction to the exhibit. The exhibit that draws the largest crowd is not necessarily the most effective. The exhibit which allows the greatest stimulation, enjoyment, and gain of knowledge to the people, has the greatest quality (Belcher, 1991, p.201).

2.4.4 Visitors

Visitors bring a wide range of ages, personal interest, subject knowledge, conceptual skills and sensitivities to museum exhibits. Each individual will not always react to an exhibit in the same manner. The more the curator knows about the visitors to the museum, the better he will be able to focus the exhibit on needs and wants of the target audience (Lewis, 1976, p.120).

Visitors are the lifeblood of museum exhibits. James Gardner and Caroline Heller state that (Belcher, 1991. p.), "An exhibition does not in fact exist until it is crowded with people, and what really matters is how these people react to what they see."

2.4.5 Museum Visit

We felt one of the best ways to observe how effective museum exhibits are designed is to see them first hand. A day trip to the Boston Museum of Science provided much valuable information that we had previously not learned through typical literary research. Throughout the visit, we kept track of how we reacted to the presentation of exhibits and how other museum visitors interacted with them.

We found various exhibits with keen attention to level of technical detail presented while balancing interactivity. An exhibit on fibre optics had one basic interactive component where two people could pick up phones and communicate with one another over a distance. Around this single interaction were various pictures and paragraphs outlining the essential details of the technology in an easy-to-understand terminology with large, clear text. A common and useful theme is demonstrated here of pulling users into an exhibit with a central interactive component and then displaying the knowledge surrounding the topic in a comprehensible manner.

An exhibit we found that was related to our topic was a weather station comparing weather data gathered from the roof of the museum to that from an actual weather service. The exhibit consisted of a model of the weather monitoring station implemented on the roof, a computer to display data from a weather service, and a device to show similar data gathered on the roof. Again, essential data were shown very clearly and caught one's attention immediately. The model of the weather station helped gain our attention and enhanced the scientific feel of the exhibit.

During the final part of our trip we analysed the computer-based section of the Science Museum. Although this section of the museum was used primarily for displaying commercial education software, we found it helpful to see how people interacted with the computers. The computer cluster was being heavily used by the typical target age group of children and their families. Our own observations of the exhibits showed that buttons for programs were large, colourful, and clearly labelled. There seemed to be careful consideration given to avoiding excessive data or too many options on each individual page.

2.4.6 Web Based Design

Our project centres on a web-based exhibit. This project offers many advantages including ease of set-up, ease of change, and ability to work on it remotely (Shneiderman, 1998, p.579). Simulation of different energy output methods can be most easily constructed via this method.

Content can be visually organised in easy to understand schemes. Colours, graphic design, and content organisation can also be implemented at a level of quality equal to that of traditional exhibits. However, users now have the option of accessing the limited amount of data they desire in individual sections instead of having to view all exhibit content at one time. This does pose the problem of designing an effective navigation system, which will allow users to quickly understand their current location and access other locations. The navigation system should be clearly organised and easily found on the current page the user is viewing (Shneiderman, 1998, p.587).

2.5 Observational Data

One method of evaluating the quality of an exhibit is observing how visitors react to it. The first step in observational exhibit evaluation is planning the evaluation (Ben Gammon – Evaluation Training, 2001). An observer needs to know what, why and how the desired information be found, and how to apply the findings. A prototype of an observation sheet must be designed and tested before the full study is to take place. Once the observation sheet has been tested, data can be collected. Enough time must be allowed in order for the analysis of the data to be thoroughly completed. For effective data to be collected from observations, it is best to describe as much as possible, since it is favoured to collect too much data rather than collecting too little.

It is often impossible to predict what is really going on in visitor's minds by just watching them. Because of this, there is a need for extra supporting data to backup assumptions made from observations. Ultimately, people's behaviours are going to change in some way while making observations of them (Ben Gammon – Evaluation Training, 2001). To insure accurate data, it is important that observation notes and records remain consistent. Taking note of actions people do not perform is just as important as recording behaviours demonstrated.

Some problems can arise from recording behaviours. Inconsistencies may result between data recorded by different observers. It is also a challenge to record all the data while the observations are being preformed (Ben Gammon – Evaluation

Training, 2001). In addition, how fast the visitor uses the exhibit can also affect the amount of information able to be described. Keeping the number of people observed to a minimum can reduce the amount of problems that can occur when recording observations. Finally, it is beneficial to spend a few minutes after the visitor has left to complete any notes.

2.6 Surveying

An important aspect of museum design is surveys. They enable the designer to evaluate the effectiveness of the exhibit to the viewing public. Performing surveys on the Museum visitors after they have used our completed site is one way to evaluate the exhibit. In conducting a survey, one must follow five main steps (Kalton, 1983, p.6). First, the objectives and the population to be studied must be defined clearly. Next, the method to collect the data must be determined along with the creation of the questions to be used to extract the data. Following the determination of appropriate questions, it must be decided how the acquired data are going to be interpreted and analysed. In the final stage, the appropriate population required for the sample from the target population needs to be determined in order for the information collected to be valid.

2.6.1 Introduction to Surveying

Surveys are used to find the characteristics, behaviours or opinions of a particular population, which, in this case, represents the museum patrons. The usefulness of a survey is its ability to determine the opinions of a large population from a properly sampled smaller population. Certain key questions must be answered in order to design an effective survey (Dillman, 1998, p.3).

- How large a sample is required for a valid survey?

- How is the survey to be conducted? By mail? By phone? In person?
- How should the surveys be collected?
- How high should the rate of response be?
- Should the questionnaire be distributed only to a select group?
- Once tabulated, how accurate are the results?

One must ensure that the sample is large enough to yield a desired level of precision (Dillman, 1998, p.5). Typically, the more respondents in a survey, the more the results gained from them are reflective of the total population. Also, within the survey group, everyone must have an equal chance of being selected for the survey. Failure to do so may bias the data in an unpredictable manner. Another consideration in avoiding bias is ensuring the questions are asked in ways which allow the participants to respond voluntarily and truthfully. Additionally, the group of participants who do respond must have similar characteristics to those who do not respond. All of these principles must be heeded to ensure the accuracy of the data obtained from the survey

2.6.2 Questionnaire Design

One may think it trivial, but the questions designed for the survey should take just as much thought and consideration as sample identification, ethics, etc (Goodman, 1999, p.6). The questions a survey pose are an essential part of research and the sole source of the data. Beyond the exact data sought out in the survey, one must consider the benefits and attention span of the respondent. The size of the survey should be minimised with regard to the amount of time each will take to complete but not hinder the accumulation of necessary data. Impromptu public surveys should not be much more than a page, and surveys that require more content should be given the appropriate setting and time allotment. Additionally, the amount of background information given to the respondent before the survey is taken should cover all the necessary topics, without too much length. The background can include a summary of the issue to be addressed and instructions for taking the survey. The wording of the background should not add so much complexity that the background requires as much concentration as the actual survey content.

2.6.3 Sequencing Questions and Question Types

The survey designer must decide the number of questions to be used, their types, and how they should be mixed (Goodman, 1999, p.8). Essentially, there are two types of questions, open and closed. Open questions allow respondents to express their opinions in their own words Closed questions provide a set of answers for the respondent and invite him/her to choose one or more for his/her answer. The survey should aim to gain the maximum amount of information from each respondent. This is best delivered through posing various open questions throughout the survey. Various closed questions should be interspersed as they provide an easier way to compare answers between surveys. Demographic questions such as age, gender, and occupation should be placed at the end of the survey in order to avoid people answering questions in a way they feel is more proper to their demographic.

Although finding out precisely what people think through open questions may seem ideal, quantifying the results with other surveys can be quite difficult (Goodman, 1999, p.8). Such questions should be combined with those that provide more of a basic skeleton to the survey response. Closed questions provide concise answers and easier tabulation of results. Sometimes the best of both forms can be combined with an initial closed question with the option to add personal comments.

In this case, data can be easily quantified and if further investigation of the subject is needed, the individual comments can be reviewed.

2.7 Interviews

Interviews are a widely used survey technique in social science and are a good way to gather information (Goodman, 1999, p.2). Impromptu and the scheduled interview are the two basic types of face-to-face interviews. Impromptu interviews usually take place anywhere there are people who most likely would have some input into the specified topic. Scheduled interviews usually take place at a person's work or home. All the interviews, except the one with Mr. Straumpf, were scheduled interviews.

Asking a distinct number and order of questions is not essentially how interviews are conducted (Goodman, 1999, p.3). The interviewer must be able to structure his questions according to the response of the participant. In order to do this, the interviewer must have thorough knowledge of the topic, know the questions exceptionally well, and understand the questions completely.

2.7.1 Interview Techniques

In order to conduct an interview there are several procedures that one might like to consider (Goodman, 1999, p.2). First a questionnaire needs to be created, in which the questions are related to the topic being covered. The possible range of answers that could be received along with responses that might not be expected must be considered. Testing of the questionnaire with other people is important so that one can see how long it takes and see if any difficulties arise while giving the interview.

It is very useful in an interview to use probes or follow up questions (Goodman, 1999, p.3). If the participant does not give a good response, it is useful to have a follow up question to try to obtain the information needed. Sometimes a short pause will cue the participant to expand on his or her answer, but too long of a pause might make them uncomfortable. The question may need to be worded differently if it is hard to understand for the participant. It can also be useful to ask the participant to repeat their answer if it is not understood. Using a tape recorder is a possible way to prevent this type of problem. Recording the interview is a simple way to be able to review the conversation for any important details that may have been missed. If an insufficient amount of information is received from an answer to a question it can be beneficial to ask the participant to elaborate. This can show the participant there is actual interest in their answers.

2.8 National Curriculum in England

It is important to understand the background of the sample before designing an exhibit and subsequent survey. In England education levels are designated by key stages, not grade levels (Department for Education and Employment (DEE), 2000). The following two key stages of focus are Key Stage 2, ages seven to eleven, and Key Stage 3, ages eleven to fourteen. The National Curriculum for England determines what will be contained in an education, sets target levels for learning, and also determines how the education will be evaluated and reported. Teachers, students, parents, and the surrounding community will all benefit from an effective National Curriculum. By understanding the methods employed in the UK for education of our target audience, we can better understand the scientific background of the visitors and how to convey data to them in the most appropriate manner.

2.8.1 Key Stage 2

1. Scientific Enquiry

Key Stage 2 is where students develop a basic understanding of what science is (DEE, 2000). At this stage they are to learn that science is about trying to explain how living and non-living things work by creatively thinking and attempting to establish a connection between causes and effects. Students are also expected to develop an understanding that it is important to try out ideas using information obtained from observations and measurements. Content for the exhibit should reflect clear scientific connections this age group requires.

2.8.2 Key Stage 3

1. Scientific Enquiry

In addition to the technicalities students are taught, they are shown the implications of such ideas on how technology develops and the benefits and detriments to society and the environment (DEE, 2000). Students are also expected to learn the scientific language involved with the ideas that they have previously learned. It is also important that students realise the health and safety implications that accompany living things, physical processes and materials.

2. Physical Processes

The details of energy that students are expected to learn deal with energy resources and conservation of energy (DEE, 2000). Distinctions are made between renewable and non-renewable energy resources. Sources such as biomass, oil, gas, wind, waves and batteries are taught in the Curriculum. It is also important for students to learn that the sun is the ultimate source of energy resources and how it relates to the formation of gas, coal and oil. The fact that electricity is generated by a plethora of energy sources is also a vital part to the Curriculum. Part of our project will focus on establishing the connection between the sources for renewable energy systems and the electricity they produce.

3. METHODOLOGY

The goal of this project involves presenting the potential output of renewable energy systems to the public, while stimulating interest in them. In order to accomplish this, we designed and developed an interactive web-based exhibit. This was followed by and evaluation of the effectiveness of this exhibit.

Many aspects needed to be taken into consideration when designing the site. From our background research, we learned the importance of designing the site to meet predetermined criteria. By meeting these criteria, we were able to develop a quality museum exhibit. This was important not only for our team in accomplishing our goal, but also for the Museum. Our exhibit can potentially be used to showcase the technologies the Museum might possibly implement on the roof. We accumulated our evaluation data by observing visitors as they used the web site and conducting a follow up survey after they had finished. Analysis of these data allowed for recommendations to be made to the Museum for future renewable energy exhibits.

3.1 Exhibit Design

As we learned from the background research, the exhibit should display content in a clear, organised and engaging manner. Content should be intriguing enough so the individual desires further interaction with the exhibit. Criteria for selection of display options included interactivity, clarity and conciseness of data, appropriateness for target audiences, coverage of necessary information, and reality of construction in the given time constraints.

Different topics that should be covered in order to have a quality grasp of the technology's potential were defined in the background research. We showcased the output for each renewable energy source on a broad and general time scale to form a general understanding of the long-term effectiveness of the system and its limitations. Additionally, we simulated the power output for these systems using the real-time weather conditions outside the museum to give users a greater appreciation for the actual potential of the renewable energy systems. Also, interactivity has been found to be an essential element in learning. Hence, it was incorporated into a section where individuals were allowed to change environmental conditions and observe how they impacted the power output for each renewable energy system.

Minor detail was discussed about the technical background of the technologies, since our focus was on showcasing the power potential of the systems. Instead, a brief statement was made about how the technology functions in order to give the user enough information to understand the outputs without overwhelming them with technical detail.

Several exhibit formats were brainstormed and each was evaluated on how well it met the criteria established previously. A adequate number of ideas were chosen for incorporation into the site which we felt accomplished the goals of the exhibit. At this point, the sections were actually designed into web-based programs and prepared for evaluation. The considerations made for each individual section and decision in the design process can be found in Appendix G.

3.2 Web Site Improvement

Interviews were conducted with key Museum personnel regarding the quality and content of the wind portion of the exhibit. The solar portion was designed after the staff interviews to avoid the same mistakes found in the wind section. The museum staff selected were those who had a history of designing effective exhibits for the Museum's target age group. Questions were structured to find whether the interviewee felt the site covered the necessary information it was designed to display, if they felt anything should be added or taken away, and if there were any general changes they felt would improve the quality of the site. Questions posed in the interview can be found in Appendix D. Once data was gathered, each suggestion for change was then considered for the site. Issues that were raised by more than one person were given the greatest consideration. All selected changes were then made to the site. Any remaining issues we decided were important were addressed in the revisions as time permitted.

3.3 Visitor Feedback Survey Methodology

It was required by the Museum that while the visitors were using the prototype exhibit in gallery we must remain in the vicinity the entire time. This was also to insure the exhibit was used properly and was not tampered with. Visitors were asked if they would like to try out a new exhibit and answer feedback questions when they were finished. Sampling involved asking parents and their child(ren) to test our exhibit once the previous group was finished. The decision for the next participant to be asked was made only with regard to the child visually appearing within the target age group. No preference was made for visitors based on gender or race.

While the Museum visitors were interacting with the exhibit, we made general observations about how they reacted to the site. As the user progressed through the site, we continued to make observations, paying particular attention to their reactions and demeanour.

All of the members of the team, each focusing on a different aspect, made observations:

- If the user was intrigued by the introduction page, or not stimulated at all
- It there was any vocal excitement expressed about a particular renewable energy technology (i.e. favouring one over the other)
- Which sections were viewed by the users
- If users appeared to read the exhibit content
- If users appeared confused by any portion of the exhibit

When the visitor finished, we politely asked them to answer questions about his or her feelings and reaction to the site. The survey contained some open-ended questions in order for us to understand what the visitor learned and the comprehension of the relationships displayed in the site. Questions on the survey were designed to evaluate:

- If we had effectively and clearly communicated the intended message of the site to the public
- If the information was presented in an intriguing and interesting manner
- The preferred renewable energy source and method of presentation.

To lessen the burden on the visitors participating in the survey, the administrator recorded the answers to the questions. We felt this was necessary in order to get better responses to the questions. We also took this approach to try to minimise the number of answers given from misinterpretations of the questions. A section was included at the end of the survey where the administrator could add any additional comments the visitor had about the exhibit. This supplemented depth to our results, adding aspects we had not formerly considered being important.

3.4 Data Analysis

Analysis was then performed on the data gathered from the Museum visitor survey. The information and insight gained from this was crucial in evaluating the quality of the exhibit. All survey data were synthesised into graphs with clear summaries of what the data suggested. To aid future exhibit decisions, information was grouped to allow Museum staff to gain an understanding of which types of renewable energy most interest the public, and in which forms of its presentation are most engaging to them.

4. RESULTS

4.1 Content of web-site exhibit

From our research, we found that the content of an effective exhibit needed to be intriguing, and displayed in a clear, organised and engaging manner. The site is structured so that the users will have an understanding of what their choices are on each page. This allows them to choose where they go in the web-site based on their interest and not a forced direction. Refer to Appendix G for an in-depth discussion of decisions which lead to the following exhibit sections.

The exhibit displays the potential power and usage of the renewable energy sources of wind and solar systems. The users first choice on the site is to investigate wind or solar energy. From the final slide of the opening animation, users are invited to click on the respective sections. Clicking on either of them will result in a title page that is similar for each of the energy sources. On this title page the user has a choice between three different sections. One contains an interactive portion, the second shows live coverage of the local weather conditions for the current day, and the third section to the monthly power potential for the renewable energy system.

Both the wind and solar sections have interactive portions to allow the user to grasp how much power is produced under fluctuating weather conditions. These sections enable the user to vary such conditions and see the corresponding affect on the power output of the technology.

To demonstrate practical application, a section of the site simulated the energy systems mounted on the Museum roof. Each of the systems was superimposed on a picture of the Museum roof to show their actual placement. A programme developed for this section continuously updated weather conditions as they changed from the CNN web site located at:

http://www.cnn.com/WEATHER/eu/England/LondonEGLL.html.

Based on these conditions, power outputs for the different technologies were calculated and displayed.

The final section consisted of how environmental conditions change during an average year to give the user an understanding of long term performance of the respective technologies. From this the public is able to see the benefits of long-term usage of these renewable energy systems.

4.1.1 Opening Animation Page

Our site begins by posing a question thus intriguing the user to investigate the exhibit further. The question reads; "What is the future of Energy in the UK?" This is displayed on the centre of the page, with a dreary city pictured below. At the bottom right hand corner, text reading "Click here for the answer" invites the user to find out more. Figure 4 shows this introduction page.

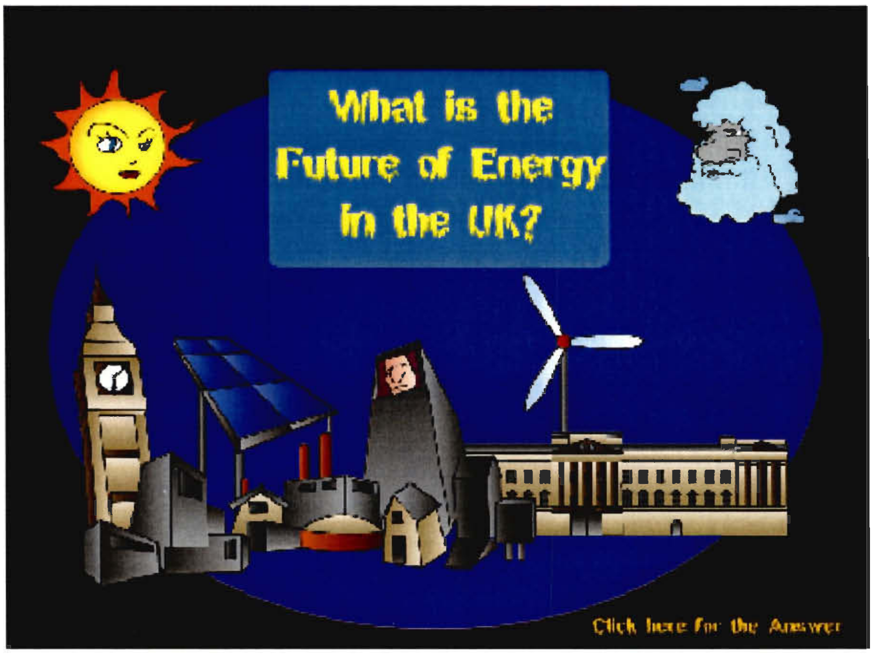


Figure 4 – Introduction Page

When this link is clicked, the sites characters, *Ms. Sun* and *Mr. Wind*, are brought in along with the renewable energy systems. The dark screen fades away and a bright and colourful scene replaces it. Now functioning renewable energy systems along with a well-lit city are shown. *Ms. Sun* and *Mr. Wind* are in the top left and right corner respectively, above their renewable energy system.

This final page of the opening animation is now what we refer to as the "home" page. Users who click the "go home" button that is located in the bottom right hand corner on each of the succeeding pages will be brought to this screen. The page allows users to select to learn about wind energy or solar energy. Each section is accessed by clicking on the either the wind turbine or the photovoltaic (PV) array. The home page is shown below in Figure 5.

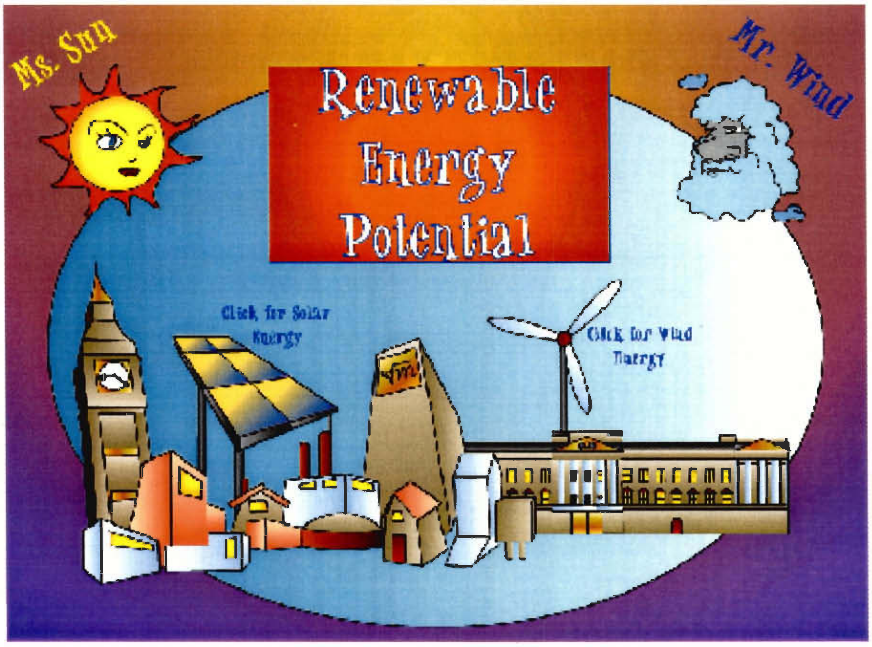


Figure 5 – Home Page

The characters were also made clickable to take into account the possibility that younger children might click on the characters for navigation

4.1.2 Wind Section

The wind menu displays a general fact about how wind energy works after *Mr. Wind* flies onto the page. This fact gives users a general idea about how wind energy works so they can better understand the rest of the information presented in the site.

Shown below the fact are the three links, *Virtual Wind*, *Live Wind Coverage*, and *Monthly Power Potential*. Each of these have a sentence or question below their titles briefly explaining what each of the different links contain. Clicking the links will bring the user to the respective section. The wind menu is shown below.

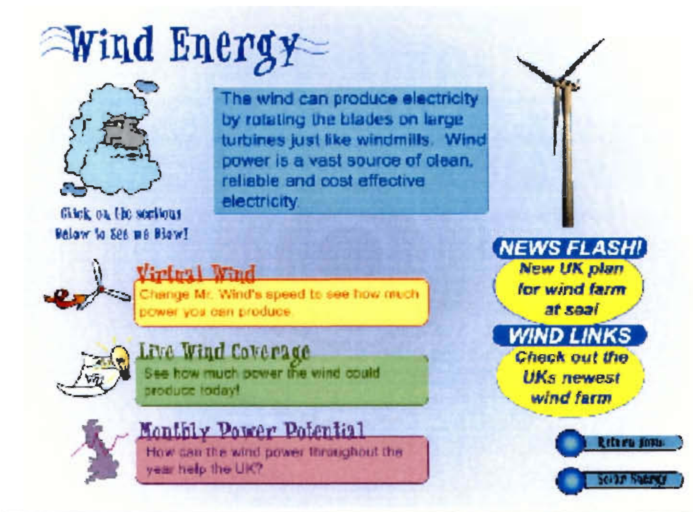


Figure 6 – Wind Menu

1. Virtual Wind

Virtual Wind contains the interactive portion of the site where the user adjusts the wind speed to see the corresponding amount of power that could be produced from a wind turbine. Instructions, including an arrow, are right below Mr. Wind explaining what to do. For added clarification, "start" and "finish" are written on the respective ends of the slider bar.

Changing the wind speed results in a corresponding change in power output from the turbine. This output is shown at the right of the screen as the number of televisions and light bulbs being powered. The colour of these items is changing along with the power input. The television screen becomes a brighter yellow as more are powered and the light rays emitted from the light bulb grow. In addition to the power output changing with wind speed, the way the turbine is functioning is also changing. Informative facts pop up below the spinning turbine explaining how the turbine is actually working within the speed range that the user is currently in. The display for virtual wind is shown below.

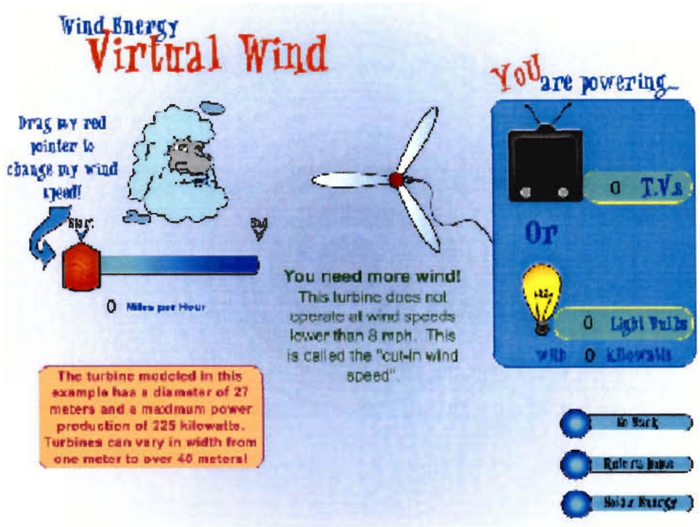


Figure 7 – Virtual Wind

Once the user has been on the page for about fifteen seconds, a paragraph about the turbine used in this example moves onto the screen telling the user about how much power a turbine this size had the potential to produce.

2. Live Wind Coverage

In this section the user does not change variables. Instead, the fluctuating environmental conditions outside the museum affect the section. A programme was written to obtain the current wind speed in London from a weather web site which was used in calculating the amount of power that could be produced by a turbine on the Museum roof. This power output is displayed on the right of the page. Corresponding amounts of televisions which could be powered are also displayed in this part of the page. The next page shows this section in Figure 8.

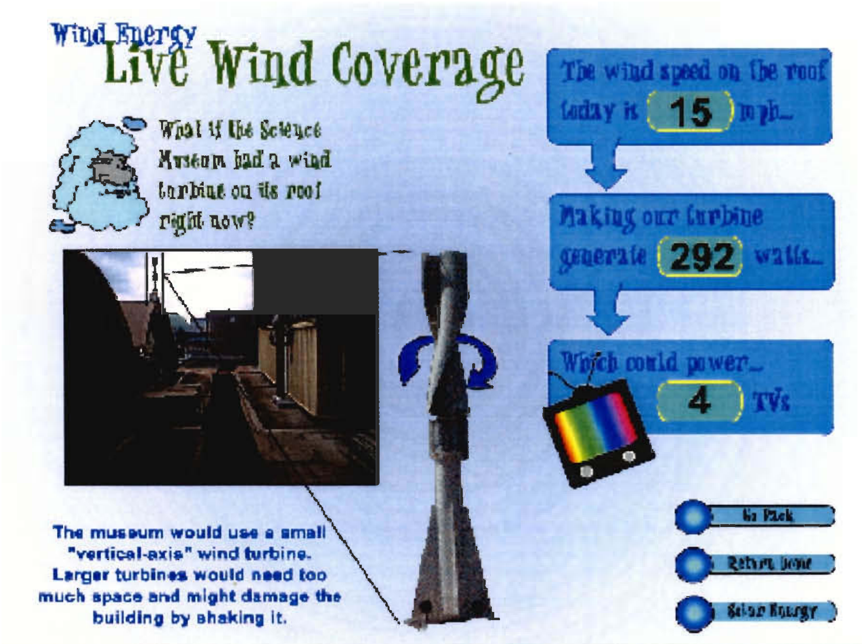


Figure 8 – Live Wind Coverage

Shown on this page of the site is a picture of the Museum roof with a wind turbine superimposed on it. The turbine shown here is the same model the Museum may soon add to its roof. A larger and more detailed view of the turbine and how it operates is also shown. Below the picture there is a factual paragraph telling about the type of turbine that could be installed on the roof as well as why conditions on the roof dictate that this particular type of turbine be used.

3. Monthly Power Potential

The main portion of this section is a graph showing wind speed throughout the year and the corresponding power output. This graph is broken up into monthly divisions, with average wind speeds for each shown. From these average wind speeds, the amount of power produced by a turbine is shown on a graph directly below. A yellow flash at the top right of the page displays a fact about the potential global use of wind power. The figure below displays the page after this fact has loaded.

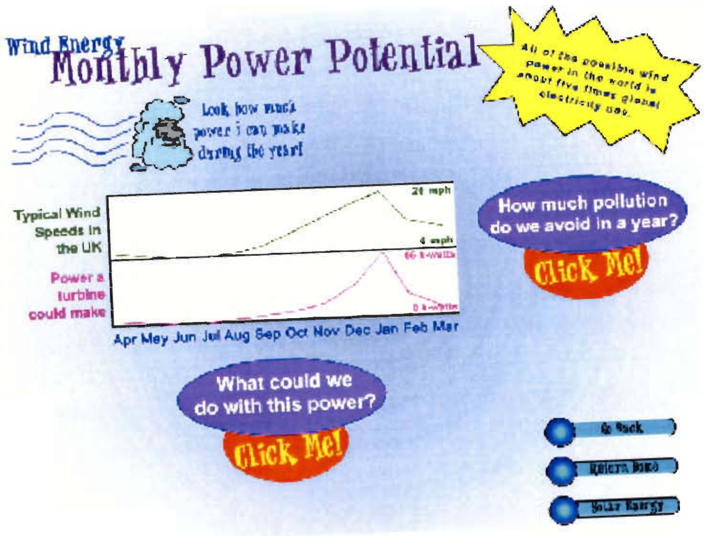


Figure 9 – Monthly Power Potential

Two sections, usage of power output and the amount of pollution saved from using wind power are located, through links, below the graph and on the right of the screen respectively. Clicking on the buttons displays additional information. The button labelled "What can we do with this power?" shows the demand each month in the UK for electricity and how power produced by the wind turbine could help to alleviate some of the power needs. "How much pollution do we avoid in a year?" shows the pollution prevented on an annual basis from one turbine along with savings that would result from all of the turbines in the UK.

4.1.3 Solar Section

Analogous to the wind menu, the solar menu contains a factual paragraph explaining how solar power works. *Ms. Sun* flies around this fact as she enters the screen. The paragraph is presenting basic facts dealing with solar energy and photovoltaic (PV) technology. Figure 10 displays the solar menu.

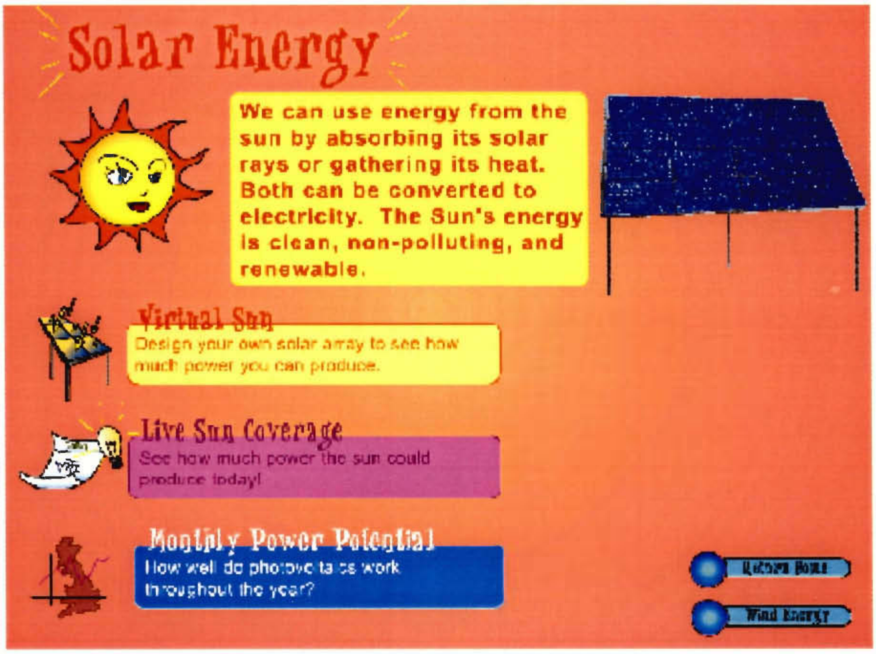


Figure 10 – Solar Menu

Again, the three menus *Virtual Sun*, *Live Sun Coverage*, and *Monthly Power Potential* are shown. Following the same set-up as the wind menus, they each contain an explanatory sentence or question showing the content of each section located in the box below the title.

1. Virtual Sun

It is through this link that users are able to change the size of the photovoltaic (PV) array. Doing this shows the user varying outputs for different sized arrays and potential of the wide range of PV applications. In addition to varying the size of the array, there is an option for adding clouds thus showing the environmental impact on the system.

Changing the size of the array informs the user about practical uses of the different sizes. This section also contains facts that pop up telling what an array that size can potentially power. Applications shown range from solar calculators to a power plant. Adding clouds is done by clicking on a button saying "Make it cloudy", which changes to "Make it sunny" when the clouds appear, allowing the user to go back and forth between the different options. Cloud cover with respect to our page refers to being totally overcast, and the resulting power is reflected by this. The page with the clouds option selected is shown in Figure 11.

Figure 11 – Virtual Sun

A fact flies onto this page explaining about the many different factors affecting the outputs of PV arrays. The factors shown are the intensity of the sun's rays, cloud cover, angle of the array and sun, along with the time of year.

2. Live Sun Coverage

A programme similar to the one used in the wind section obtains the current solar weather conditions for London. This information is from the same web site from which the wind speeds are retrieved. Weather conditions are described corresponding to current cloud cover.

Another photo of the roof is shown here with a PV array superimposed in place. The PV panels are placed as they would if construction takes place. The figure below shows this section of the site.

Figure 12 – Live Sun Coverage

Below the picture, specific facts are shown about the potential PV array that the Museum may place on its roof. Described is the size along with when the maximum power output from the array can occur.

4. Monthly Power Potential

The main focus of this section is two graphs comparing monthly sunshine hours in the UK and the corresponding power output from a PV array. A fact explaining the solar energy absorbed by the earth in one year compared to the word's supply of fossil fuels zooms onto the screen after about fifteen seconds. Below the graphs of sunshine hours and corresponding power output, is an information button that reads "How can this be improved?". Clicking on this button displays a graph predicting efficiency improvements over the next thirty years. The graph shows the output now, in 2005, 2025 and finally 2030. Text is also shown to the right of the graph explaining how research may eventually triple the efficiency of PV cells. The figure below shows this page with all the options selected.

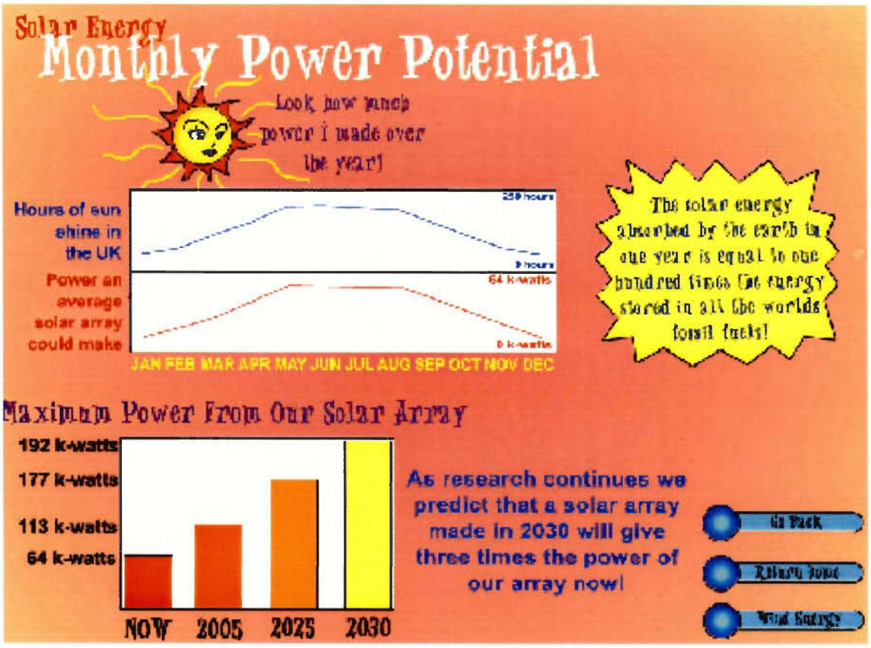


Figure 13 – Monthly Power Potential: Solar

4.2 Evaluation Data from Museum Staff

Museum staff were invited to view and evaluate the wind portion of our web-site before we went on to develop the solar section. The same rough draft of our site was used for each of the interviews, which ranged in length from thirty minutes to an hour, depending on the amount of comments the interviewee had while surfing through the site.

A total of six interviews were done, with both exhibit and exhibition developers and energy gallery team members. We felt it would be very beneficial to gain perspectives on both technical aspects of our site and its presentation and layout. They both proved to be very helpful regarding changes needed to improve the site. Minutes of the interviews can be viewed in Appendix E.

4.2.1 Exhibit and Exhibition Developers

Three employees we interviewed were involved with developing exhibits and exhibitions. Interviewees included Owain Davies, an exhibition developer, Nicky Lewis, an exhibition developer, and Emma Freeman, an exhibit developer. Each individual had many comments and the interviews lasted approximately an hour each. Insight gained from these three interviews was very valuable in adding to the presentation of our web site.

Many of the comments and ideas gained from these interviews were mentioned consistently, so particular attention was paid to these revisions. The comment that we received most frequently was that we had presented too much information at one time. Suggestions were made on how to break up this content either through time-lapses between showing information or through interactive pop-up menus. Mr. Davies, Ms. Lewis and Ms. Freeman all mentioned their eye was confused by the amount of content on the main wind menu.

4.2.2 Members of the Energy Gallery Team

Three members of the Energy Team were interviewed; Peter Davison, the Project Co-ordinator for Energy, Dr. Alan Morton, the Senior Co-ordinator for Modern Physics and Sophie Duncan, who gave us not only insight on how the information was presented, but additional content that could be added to enhance the site. The duration of these interviews was about thirty minutes. Since these energy experts have backgrounds different from the exhibit and exhibition developers, the comments we received from these interviews were different as well.

The information we obtained from these interviews was slightly more difficult to incorporate into the revisions since most of them included a substantial amount of time required to implement the changes. All of the comments made were valuable, but some would be more difficult to implement within time constraints. Comments made during these interviews can be found in Appendix E.

4.3 Survey Data from Public of Exhibit in Gallery

The completed web exhibit was brought in Gallery and patrons of the Museum were asked to try it out and give feedback. The exhibit was brought to the flight lab section of the museum. The flight lab was chosen because it was described as an area of the museum frequented by our target age group of seven-to-fourteen year olds along with their families. This area also features a motion ride, a very popular attraction for school groups. The laptop that contained the web-based exhibit was set up on a table in the café across from the flight lab where people either entered or exited the gallery. This was a prime location because people were on their way out of the gallery, so asking them to test out a prototype exhibit did not bother them while they were experiencing other exhibits.

The survey feedback resulted from a questionnaire we had developed. It was structured to see if we had communicated our intended message effectively, to see if the site was interactive, informative, and interesting, and finally to see if there were any sections or energy sources that were of most interest to the public. In addition to the information obtained from the survey, observations were also made of the patrons as they used the exhibit. An observation sheet was designed to help monitor the usage of the site while the visitor was engaged with the exhibit.

4.3.1 Results from Observations

All observations were made prior to our feedback survey which took place on April 11th, 2001 and April 12th, 2001, in the flight lab. Observations were made to gain a greater understanding of how the user went through and reacted to each section of the site. This information was gained by watching people's facial expressions and listening to the users communicate with one another. Note that observations generally are to some extent subject to the bias of the observer.

Observation 1

How did the users react to the opening animation?

The first observation made was seeing the reaction of the users after they viewed the opening animation. The design process of the opening animation was intended to catch the eyes of museum visitors so that they would want to try out the site once on gallery. This observation was important to see if this design objective was successfully achieved. Although we did not observe an overwhelming reaction to the opening page, no one appeared to have a negative reaction.

Observation 2

What did the users say to each other and you?

This observation was used to see if the user was getting a good grasp of the site. By asking questions or discussing different aspects of the site with one another, users showed that they were involved and interested in its presentation and content. This was also a useful tool in discovering if there were any confusions or misunderstanding in content or navigation. Overall, observations were made of the users discussing the different sections among one another and even making predictions in different case scenarios. An example of this was when a parent asked their child in the live wind section, "if the wind speed increased or decreased, how would it affect the power output?" From this the child was able to give a correct response. Another example of discussion was when a California family were talking while in the virtual wind section of the site. The father was explaining to his three sons that at a certain point a turbine reaches maximum power and it does not matter if the wind speed increases, the power output will stay constant. He explained all of this to his sons prior to trying this section of the sight and his knowledge proved to be true.

Observation 3

In what order do the users go through the exhibit?

This observation recorded what sections of the site were visited by each users. Seeing which sections people visited and how long they stayed in each section reflected interest in different areas of the site. Since one of the goals of the site was to see if people had a preferred energy source they wanted to learn about, this observation resulted in useful information in finding out the relative interest between different energy sources and exhibit formats. Once inside each of the respective sections, the user often went through each section one at a time starting from the top with the virtual sections and finishing up at the bottom with the monthly power potential sections. It was also observed that the users spent most of their time in the virtual sections and spent the least time in the monthly power potential sections. Both the wind and solar sections were viewed with nearly the same frequency as seen in Figure 14.

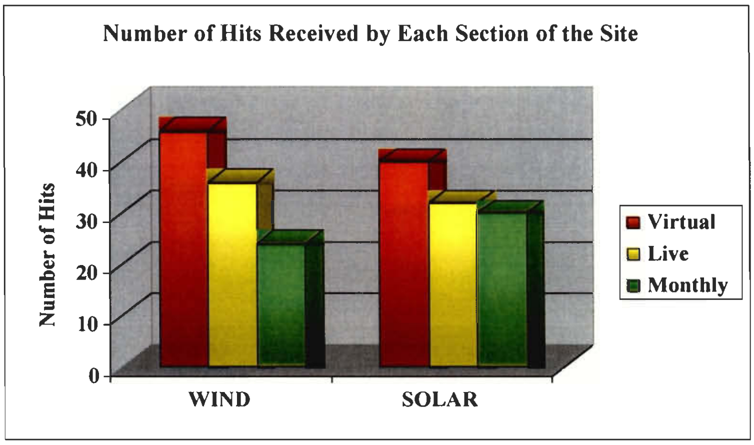


Figure 14 – Hits Per Section

Observation 4

Do the users appear to understand the buttons and links?

The purpose of this observation was to find out if the buttons and links in the site were clearly marked and labelled to allow ease of use and navigation. Since the focus of our site was seven to fourteen year olds, making the sight easy to navigate was an important aspect, since at such a young age, children might have little to no prior computer knowledge. Figure 15 shows that there was a very good understanding of all the buttons and links. More specifically, everyone in our target age group except for four girls in the ten and under category understood the buttons and links. Based on observations, older users not understanding the buttons and links was often due to a lack of prior computer knowledge.

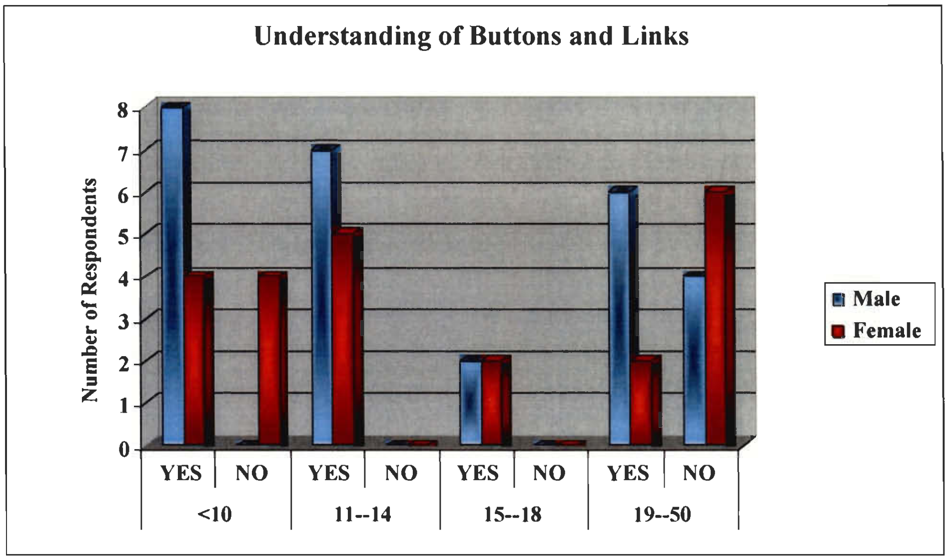


Figure 15– Understanding of Buttons and Links

Observation 5

Do the users appear to read the exhibit content?

The purpose of this observation was to see if the user was reading the content or just quickly going through the site paying minimal attention to the detail of the content. This observation was important because in order to communicate and understand the intended message of the sight, one must read the content. Figure 16 below shows that everyone except for two males in the ten-and-under age category appeared to read the content of the site.

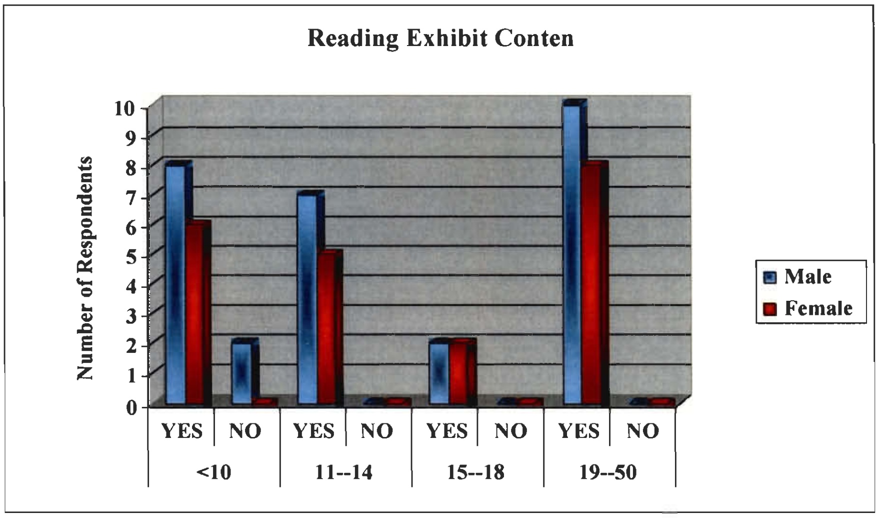


Figure 16 – Reading Exhibit Content

Observation 6

Do the users read the interactive instructions? Did they appear to understand them?

This observation was made to determine if users properly understood how to use the interactive section of the site. If they did not, instructions and formatting would have to be improved. Observations showed that almost all of the users properly understood the interactive section. Even some users who had no prior experience using computers eventually discovered how to properly use the section.

4.3.2 Results from Survey Questionnaire

There were a total of fifty visitors who tested our exhibit and took the time to answer our feedback survey. Out of the fifty visitors surveyed, twenty-four were in the seven-to-ten and eleven-to-fourteen age ranges.

The graph in Figure 17 shows a demographic breakdown of all the visitors we surveyed. This graph shows the majority of the visitors we surveyed were within our target age group. Children who used our exhibit often did so with the rest of their family. This is reflected in the graph since we felt it was also necessary to sample a broader age range to include typical family ages.

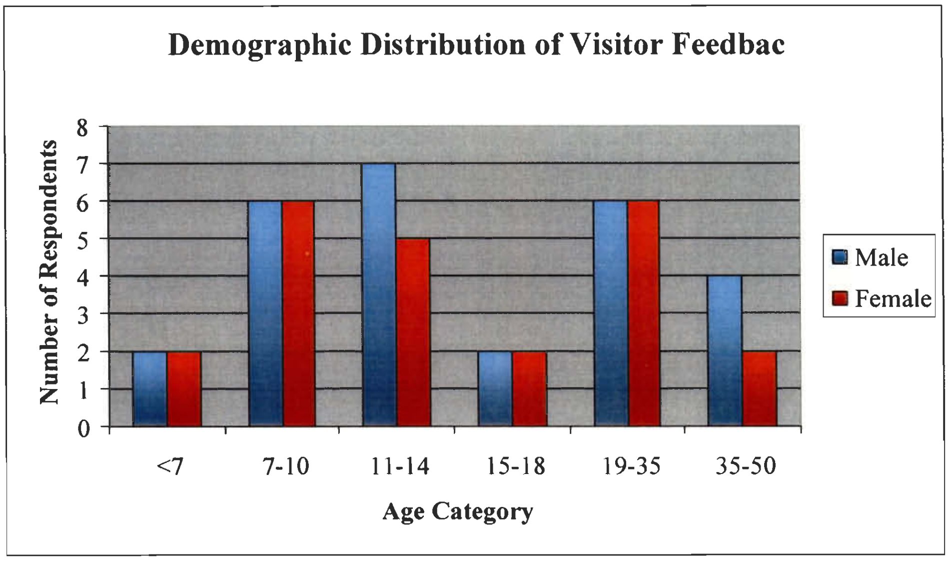


Figure 17 – Demographic Distribution of Visitor Feedback

Question 1

What do you think this exhibit was trying to show you?

The exhibit was trying to show the potential benefits and performance of such technologies as wind energy and solar energy. This question was to determine if we effectively communicated to the users this intended message. The results show that the message the users received closely corresponded to our intended message of showcasing the potential performance of renewable energy systems. However, the responses of "What to do with the roof" and "Power of Electricity," were felt to reflect an improper understanding of the exhibit. Even so, 80% of the population properly interpreted the intent of the exhibit.

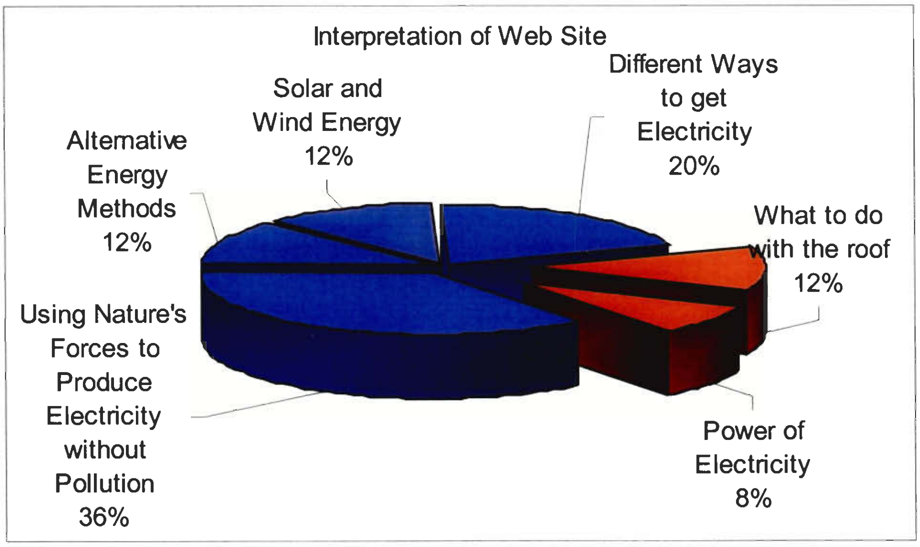


Figure 18 – Interpretation of Web Site

Question 2

Did you find the information that was in the exhibit interesting?

The purpose of this question was to find out if the users thought that the content in the exhibit and the exhibit as a whole were interesting. One goal of our project was to display the information in a manner that would stimulate people's interest. We found 100% of the survey population found the information in the site interesting. These results are graphically displayed in Figure 19 on the next page.

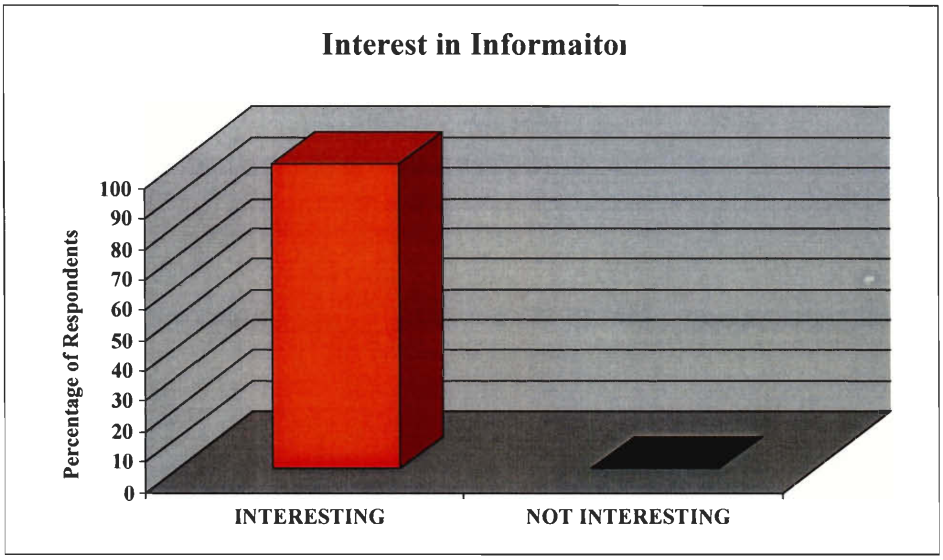


Figure 19 - Users interest in Presented Information

Question 3

Were there any words or sections in the exhibit that you found confusing?

The purpose of this question also dealt with how effectively the intended message was communicated to the users. This question was designed to determine if visitors actually understood the content presented.

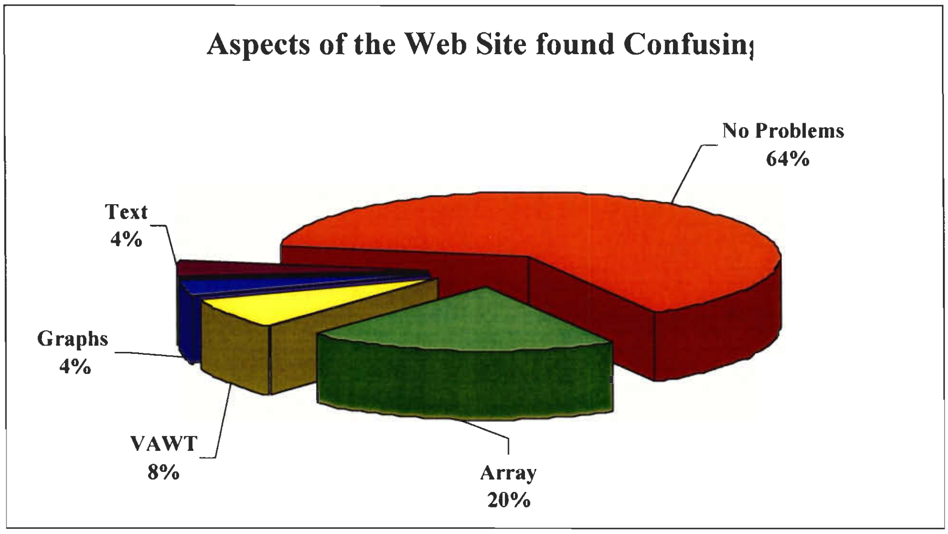


Figure 20 - Confusing Sections of the site

The data collected shows that 36% of the people did not fully understand the content in our exhibit. After further investigation, we found out that most of the misunderstanding was from some vocabulary issues. More specifically, some visitors did not understand the word "array" and did not understand what a "vertical axis wind turbine" was. Some of the technical information, such as the graphs and corresponding text in the monthly potential sections was difficult for younger people to understand.

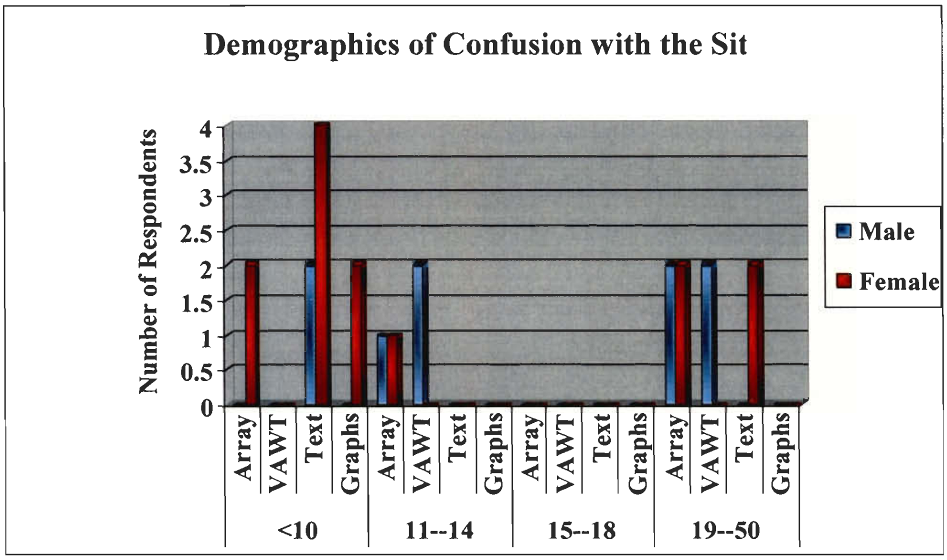


Figure 21 - Demographics of Confusion with the Site

Question 4

Did you like the characters Ms. Sun and Mr. Wind?

The purpose of this question was to make sure that the user would stay engaged and involved in survey. Since our target age group was seven-to-fourteen year olds, we felt it necessary to ask this question about midway through the survey. We did not want the users to lose focus, which younger people often do. Figure 22 on the following page shows that the majority of the survey population preferred *Mr. Wind* to *Ms. Sun*.

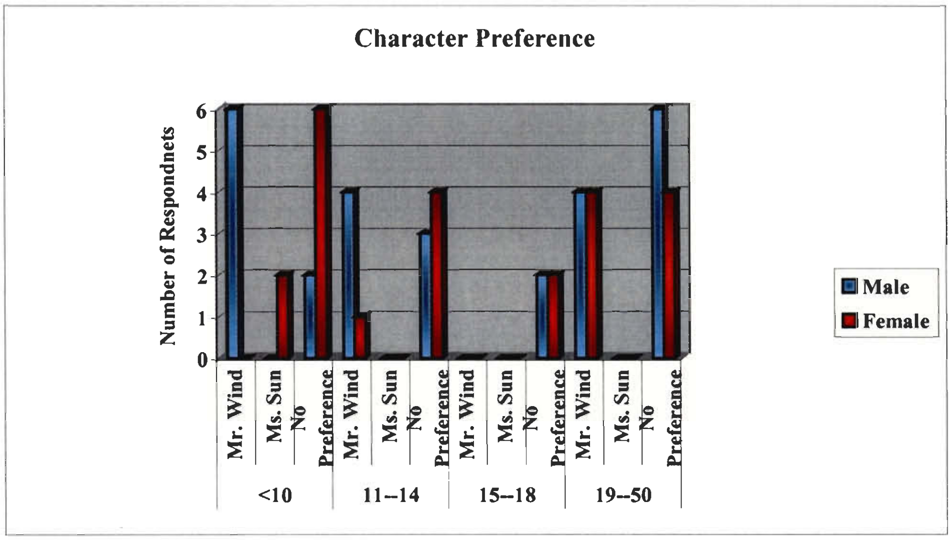


Figure 22 - Character Preference

Question 5

What did you like the most about the exhibit?

We asked this question to help us identify different areas that users liked the most.

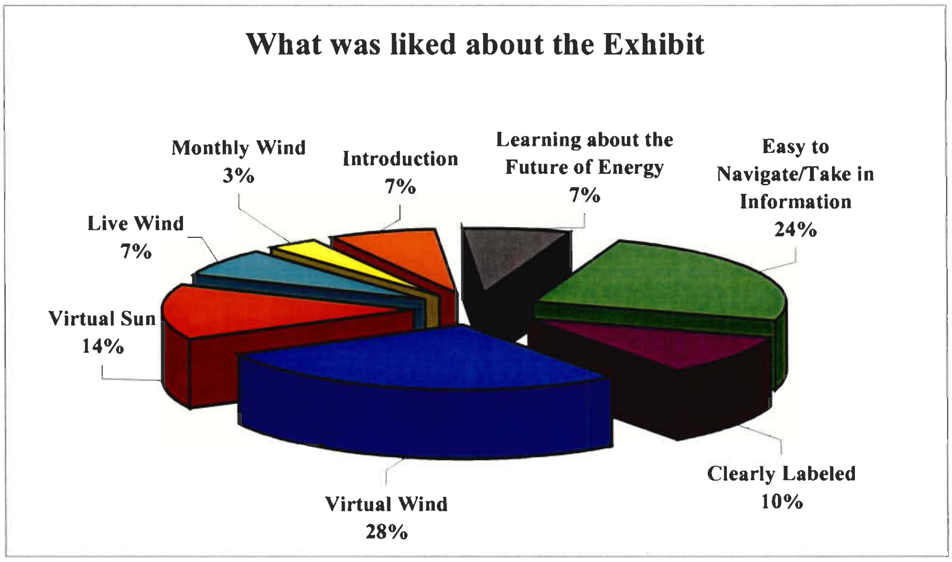


Figure 23 - Liked Aspects of the Exhibit

If the users' initial response did not refer to a specific section of the exhibit, we then followed up with a prompt question asking what particular section of the site they happened to favour. Shown below are the results from this question. Clearly, most of the survey population preferred the interactive portions.

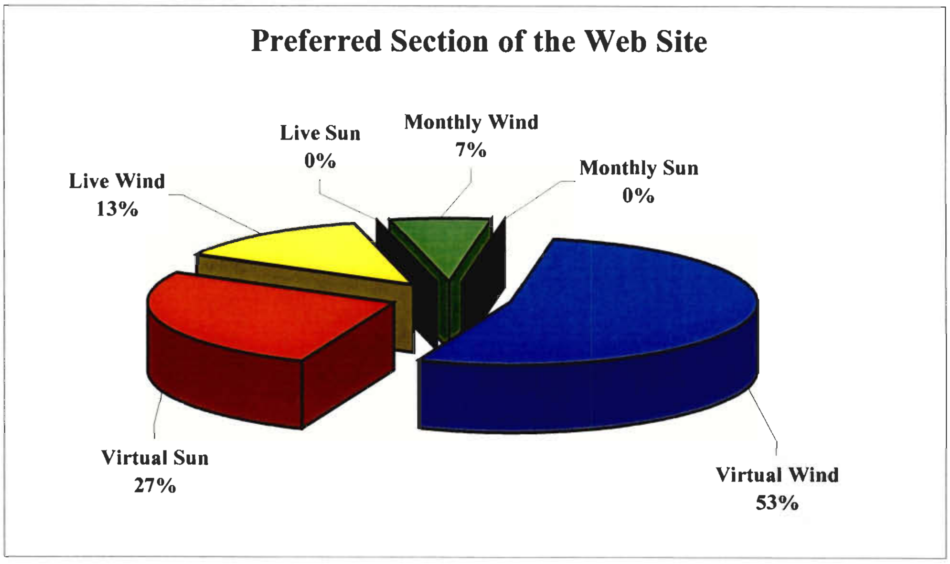


Figure 24 - Preferred Section of the Web Site

Question 6

What did you like least about the exhibit?

Similar to question five, we asked this question to identify different areas that the user did not like. The graph in Figure 25 shows that 52% of the people had nothing they disliked about the exhibit, while the remaining 48% was divided up between monthly graphs, menu too small, and text being difficult to read. Of those that disliked something about the exhibit, 28% of the people did not like the graphs in the monthly power potential sections, 12% thought that the navigation menu in the bottom right hand corner of every screen was too small, and 8% found some of the text hard to read. Several of the children below the age of ten had trouble with the graphs in the monthly potential sections.

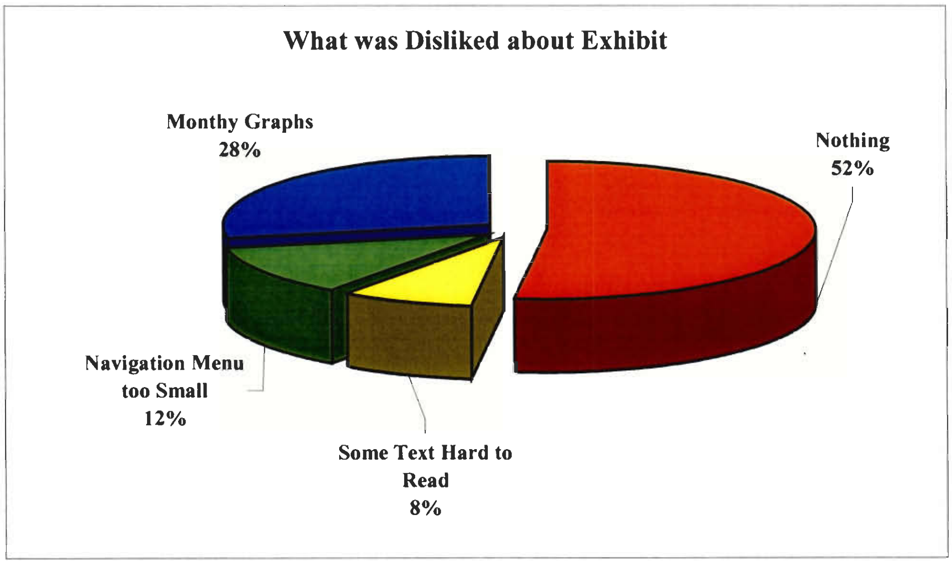


Figure 25 - Disliked Aspects of the Exhibits

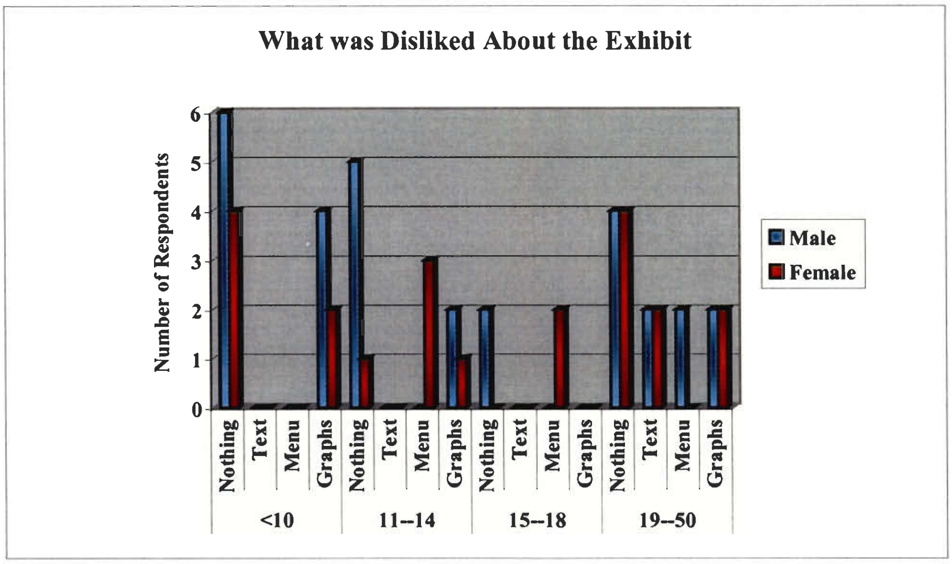


Figure 26 - Demographics of Disliked Aspects

Question 7

Did you have a preference for learning about wind power or solar power?

This question was designed to find whether a preference existed for learning about one energy source or the other. This information may assist the Museum in making future exhibit decisions. As seen in Figure 27, although 48% of the population had no preference for either source, of those that did, 44% preferred wind power over solar.

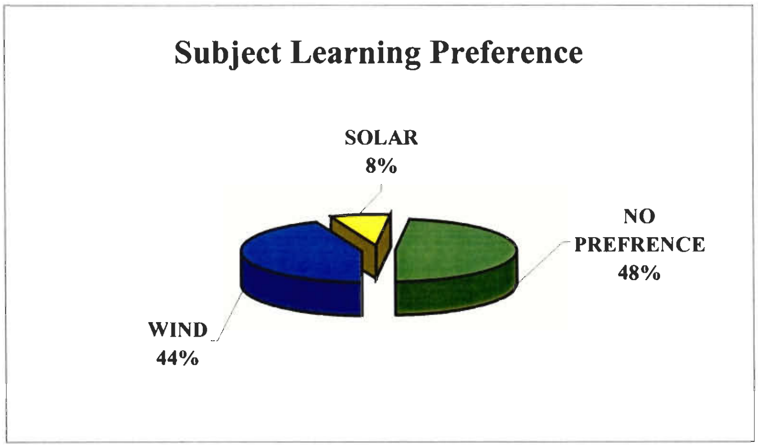


Figure 27 - Subject Learning Preference

In addition, we broke the learning preference down into age categories and gender to see if there was any significant difference between the groups. Although 48%, which was the biggest percent of people, did not have a preference, the graph below shows that the 44% of people who preferred wind was spread out almost equally between all the different age categories. The remaining 8% who preferred solar were split equally between the eleven-to-fourteen and the nineteen-to-fifty age categories.

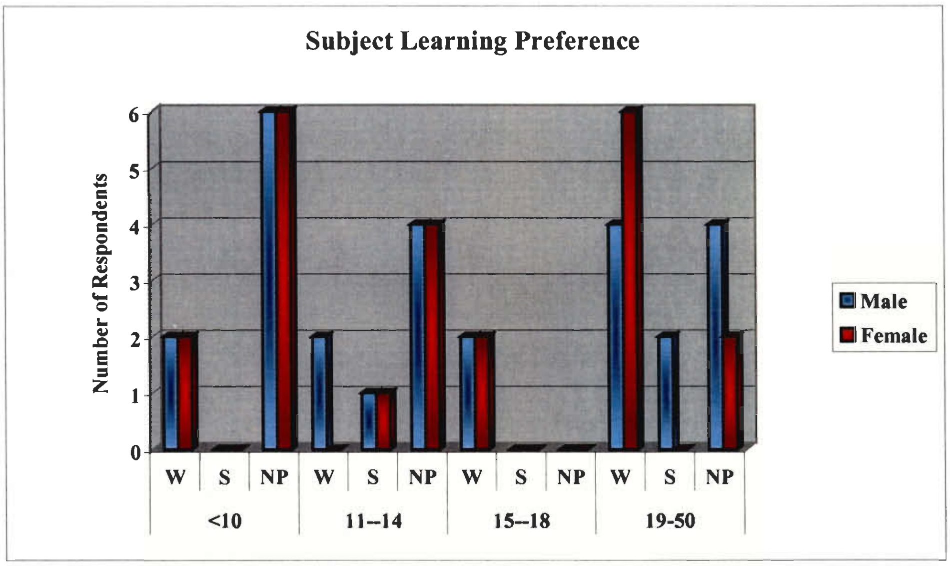


Figure 28 - Demographics of Learning Preference

Question 8

If you saw this exhibit in the Museum, would you use it? Please circle one. Definitely Not (DN) – Probably Not (PN) – Probably (P) – Definitely Yes (DY)

After visitors had viewed the exhibit, this question was posed as a final method to assess visitor enthusiasm for the site. Discrete answers were used to make the data gathered more easily quantified. An average answer of "Maybe" was eliminated after discussion, to force users to make a more concrete decision. Data indicates that museum visitors would indeed use the exhibit were they to come across it on the gallery floor.

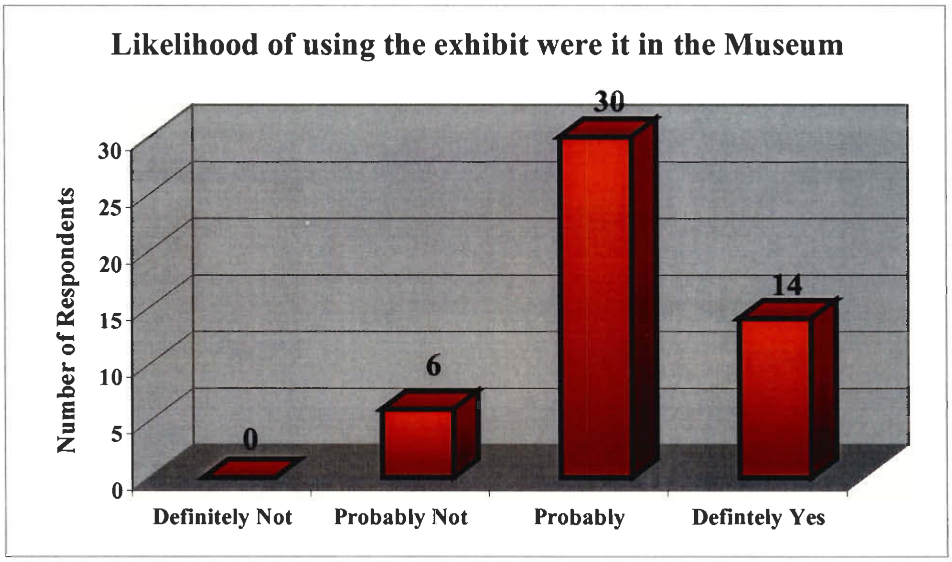


Figure 29 - Usage of Exhibit in Museum

In addition to the overall breakdown, the results were further organised into age categories and gender to see more specifically where the biggest responses were. The figure below shows that the target age group of seven to fourteen along with their parents in the category of nineteen to fifty gave the largest response that they would probably or definitely use the exhibit if it were in the museum.

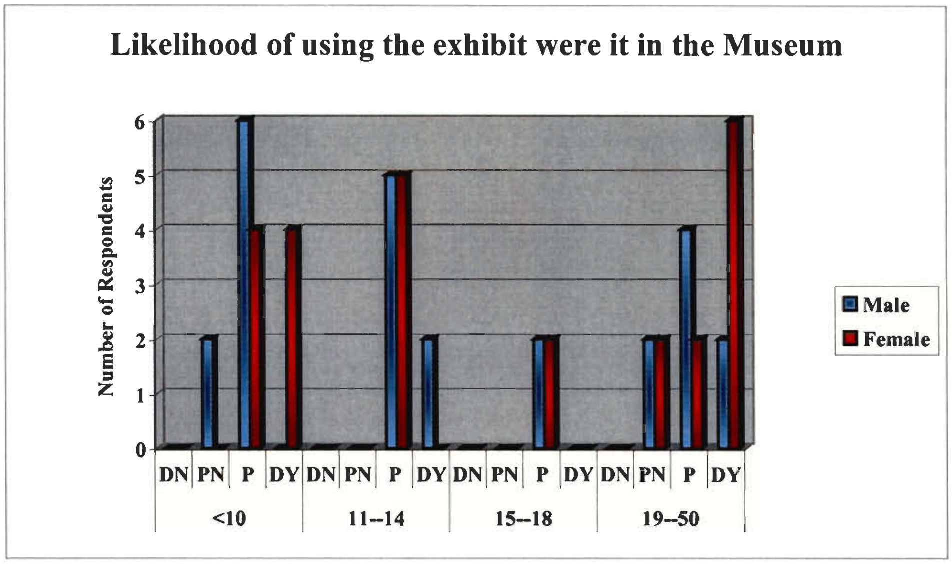


Figure 30 - Demographics of Usage

Question 9

How clear was the use of televisions to show amounts of power? Please circle one.

Very Confusing – Confusing – Clear – Very Clear

An essential portion of various sections of the exhibit included how the concept of electrical power levels was interpreted to make them understandable to the public. Varying numbers of televisions was used to quantify electrical power quantity of Watts. Although general questions about confusion in the site were addressed earlier, this concept was addressed individually as it is most critical to understanding the information in the exhibit.

Some visitors did find this concept confusing but an overwhelming majority had little or no trouble understanding working televisions as power quantities. By successfully showcasing this concept, users could more easily learn the concepts of renewable energy system characteristics.

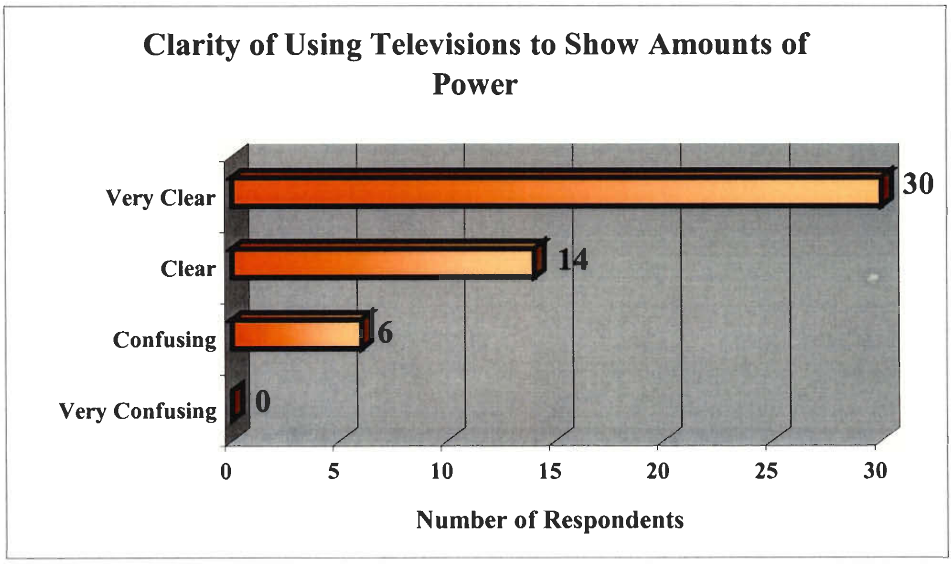


Figure 31 - Clarity of Using Televisions

This question was structured to evaluate if the targeted audience understood televisions as a tangible item that they could relate power to. There was an overwhelming response from the target age group of seven-to-fourteen and their parents in the category of nineteen-to-fifty that understood this representation.

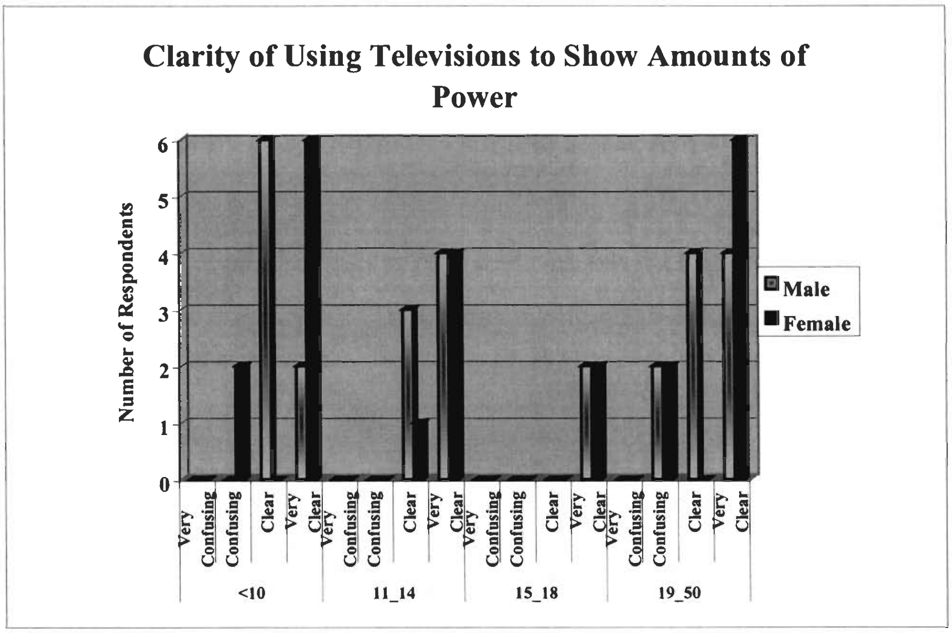


Figure 32 - Demographics of Figure 4.28

Question 10

Please Circle any words you feel describe the exhibit:

Fun	*Clear*
Confusing	*Plain*
Easy to use	*Hard to use*
Uninformative	*Informative*
Creative	*Other*
Boring	

This question allowed users to express their feelings on the exhibit in a more quantifiable nature. We wished the site to be informative, clear, easy to use and fun. We supplied these answers along with their antonyms for users to select. Other applicable words were added to gain a greater and quantifiable picture of visitor's opinion of the site. From the data, descriptions of the site matched the intended characteristics of the site. Informative, clear, creative, easy to use, fun each received a sizable response while their respective antonyms were selected few times. This data can be viewed in Figure 33.

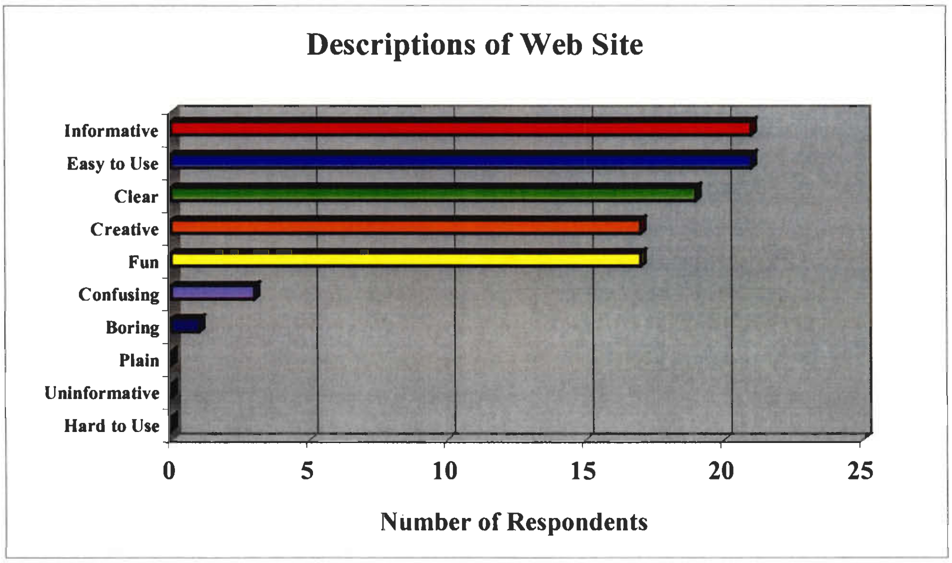


Figure 33 - Descriptions of Web Site

5. ANALYSIS

5.1 Museum Employee Interviews

After the six interviews were completed, a list was generated of all the comments and suggestions made. Many comments were repeated and others were only mentioned once. Repeated suggestions were given the most consideration for implementation but single observations were also considered. A list was generated of all the comments and suggestions made for easy perusal and to ensure that no comment would be looked over. After discussing the comments and suggestions, the team collectively decided on which changes were going to be made and those that were not.

5.1.1 Changes Made to Web-Site and Why

The most frequent comment we obtained from our interviews was that too much content was presented at once. This applied to almost every page of our site. Even though the content of our site was considered to be excellent, the manner in which it was presented was thought to be a bit overwhelming. To alleviate this problem, some content was brought onto the page about fifteen seconds after the page loaded. Another method involved clicking a button which would then have the content appear. Using both of these methods broke the data we wished to present into more understandable parts. Users would now have a much better chance of taking in all of the information we presented.

Insights were also given to the wording of some of the facts presented in the site to avoid having too many words or complex terms that children might not understand. This led to rephrasing and rewording a few of the factual paragraphs.

Some of the text was shortened, but care was taken to make sure that it still contained enough information to get the initial message across.

1. Opening Page

It was also brought to our attention that the opening question wasn't giving the user the correct impression of what the site was intending to show and needed to be modified. The question was changed to "What is the future of Energy for the UK?", which was felt to be a better precursor to the answer of "Renewable Energy Potential" than "Does the UK have a Future in Energy?". The latter seemed to indicate that the UK might not have a future in energy which certainly is not true.

A colour issue was also raised concerning the PV array. Its original colour was too close to the background colour, so the array shade was lightened so that a distinction could be better made. We also received a suggestion about how to make the renewable energy systems more noticeable by not having them appear on the initial page. We fixed it so that the systems now fade in from the background as *Ms. Sun* and *Mr. Wind* appears on the page.

2. Wind Menu

The initial text box on this page was thought by most of the interviewees to be too wordy. They felt too much was said in one place and recommended it either be broken up into different sections or shortened. We decided to shorten the text because we were still able to get our message across in fewer words. This option was used since we are trying to appeal to children, who may not read the fact if it is too long.

It was also brought to our attention that when Mr. Wind flew onto the page that he blocked some of the text in the box. We wanted to draw attention to this box, but because of this, it just made it more difficult for the user to read the fact. So his path was changed so that he now circles around the box, drawing the user's attention there, without hindering the reading process.

Another suggestion made to us was that the instructions below Mr. Wind stating "Click below to see me blow" wasn't clear what to click or what was going to happen as a result of this action. For added clarification, we changed the text to "Click on the sections below to see me blow".

3. Virtual Wind

This page, too, was felt to present too much information at once. The fact we had on this page regarding the wind turbine used for calculating the wind speed ended up needing two revisions. Initially, it had contained too much detail about the geographical location of the turbine, which the interviewees felt the user would not be concerned with. So we shortened it to contain just vital information. Also, since there is a lot of content on this page, we had the fact fly in after about fifteen seconds. This gave the user enough time to take in what was happening on the rest of the page.

There were also some suggestions made about making our interactive portion easier to use. The word "slider" was thought to have the possibility of confusing the user, since not everyone may know what was meant by the word. So we changed the instruction from "Drag my wind slider" to "Drag my red pointer", since this instruction was clear about what we intended the user to do. For added clarification we included an arrow that extended from Mr. Wind's directions to the pointer, so there would be no misunderstandings about how to use this section.

Additionally, it was not clear how far the slider would move when adjusting the wind speed. Initially, the only marking on the slider was the changing wind speed. We had made the assumption that users would understand that they were able to go all the way from one end to the other of the slider and see the full range of wind speeds. Upon testing our site with the Museum personnel, it was noted that users may stop before they reach the cut-out speed of the wind turbine, which is an important fact that must be understood about wind energy technology. To make sure that a user would go all the way to the end and view this fact, we placed "Start" and "Finish" arrows on respective ends of the slider bar.

One of the popup facts explaining how the turbine works contained terms that were felt to be difficult to understand by children. The word "cube" and "proportional" explaining the relationship between wind speed and power output were suggested to us as terms that children would have a hard time comprehending. Our initial fact went on to explain what this relationship meant, saying that doubling the wind speed resulted in eight times the power. Since we explained the concept in child-friendly terms, it was really not necessary for us to use the technical terms, since the basic concept could be portrayed without them.

4. Live Wind Coverage

This page also presented too much information. The fact we had on the page about small wind turbines being significant was suggested to us as redundant, since everything else that we presented on this page already relayed that fact. So we decided it was best to omit that fact from this page. This helped to decrease the busyness of the page.

The main focus of this page was to show current weather conditions and the corresponding amount of power that could be produced if the proper hardware was on the Museum roof. The wording of the text regarding the wind speed on the roof did not make it clear that it was the actual speed today. Words were changed so that it was in a more explicit form the user would understand. The text now reads "The wind speed on the roof today is….".

Finally, a yellow box that contained some factual information was in a font that was difficult to read. This was simply improved by putting the text in a font that was much easier to read.

5. Yearly Power Output

The first comment we received about this section concerned the title. The information that we presented in this section really dealt with monthly power outputs during the year, not a yearly output figure. So we changed the title to "Monthly Power Potential".

Originally we had included a fact about wind turbine's energy payback time of three to five years. From our interviews, we found that this fact was regarded as not being useful and cluttering the page. Since we had enough other facts on this page that we felt were more important, we omitted this fact with out diminishing our content.

The text we put in about the potential for global energy use was revised so that the information was clearer to the user. There was also too much text displayed on the page, dealing with different concepts. To solve this problem, we created buttons that the user could click on to obtain more information. These buttons linked to facts about the demand for energy in the UK and also the amount of pollution that would be saved by using wind energy technology.

5.1.2 Changes Not Implemented and Why

Some of the staff expressed to us a few creative and fun ideas for additional content that could be added to enhance our site which couldn't be taken into consideration at this stage of development. These changes were more involved than changing wording or presentation of data. Some applied to graphical considerations, others to new content altogether.

1. Graphical Suggestions

The comments we received about the site's graphics dealt with the opening animation page. In the first frame, one of our interviewees felt that the illustration of Buckingham Palace was too detailed and overwhelmed the page. It was suggested that we take out the windows so that the building would blend with the rest that are present on the page. So in response we took out the windows, but decided that we liked how it looked with the windows still intact so it was our final decision to leave them in.

Another graphical consideration brought to our attention was the detail of the building that is the Science Museum. After looking at the outside design of the Science Museum, we found that it didn't have any distinguishing characteristics, so that any detail we added wouldn't be recognised by the public as the Science Museum anyway. Because of this we decided to focus our efforts on revisions of more benefit.

It was brought to our attention the possibility of adding in people that were lying on the ground while the city is dark, and as the city lit up, the people would get up and start walking around. While creative, this idea would have taken a lot of time to design and create, so due to our limited development time, this wasn't one of the practical improvements that could be made to our site at this time.

The path of Ms. Sun rises from the bottom left of the screen to a stationary position at the top left-hand corner. It was suggested to us that we have the *Ms. Sun* rise from the right of the page then end up on the left side, like the sun rises every day. We enjoyed how our characters entered the screen symmetrically, and the technical changes that would have to be made involved too much time that could be allotted at this stage of development. Also, since we only received this comment from one out of the six people we interviewed, we felt although still important, it was not imperative we make this change.

2. Content Suggestions

In our Virtual Wind and Live Wind Coverage sections, one of our interviewees offered us the idea of creating a link that users would be able to click on to see how the power output could run other household appliances. We all agreed that this would add to our site, but came to the conclusion that we needed to develop the entire site before adding additional content. This addition would require research into the amount of power required by various household appliances and also graphic design and technical programming.

We also receive two general comments about additional content that could be added to the site. It was suggested that we add in a map of existing wind farms in the UK along with the use of wind energy throughout the world. Although a map of wind farms in the UK was excluded, in the final stages of site development we added links that connect to outside sources explaining how offshore wind farms work and information about the existing offshore wind farm in Blyth.

Adding sound to the site was given to us as another option that would interest children. The technicalities that would have to be used and learned to employ this feature were too complicated in this setting.

5.2 Evaluation of the Public

After survey data were properly organised, they were summarised to evaluate the exhibit's success in the content and communication of the intended message of the site. Furthermore, the analysis also gave insight into whether users preferred learning about solar or wind energy. Also, the data enabled find which exhibit format users most preferred.

5.2.1 Summary of Exhibit Communication Quality

In order for the exhibit to be successful, it must communicate its information in a clear and concise manner. Based on the fact that 80% of the users properly interpreted the intended message of the site, and 64% of the survey population found no confusion with the exhibit, we can conclude that our intended message was communicated very effectively. Of the 36% of the survey population that found confusion within the site, such confusion drew from minor issues such as vocabulary problems.

In addition to the survey results, the observations made suggest the same conclusion. These observations suggest that 80% of the users understood the buttons and links to include 75% of the target age group. Coupled with the fact that a vast majority of the target age group appeared to read the exhibit content, it can be restated that the content was presented in a manner that clearly conveyed the site's intended message.

5.2.2 Summary of the Exhibit Content Quality

Although the communication must be clear, the information presented is the true essence of the exhibit. Care must be taken in data analysis to ensure that the content is proven to be interactive, interesting, and intriguing. The survey results showed that 100% of the survey population found the information in the exhibit interesting. Additionally a vast majority described the site as informative, creative and fun. Both results allow the conclusion that the information in the site is both useful and intriguing. Furthermore, observational data supports this point. Very often, the content was interesting enough for many family groups to enthusiastically discuss the information shown.

5.2.3 Summary of Preferred Energy Source

The second objective of the project was to determine whether Museum visitors had a preference for wind power exhibits or solar power exhibits. Various pieces of data suggest that visitors are more drawn to and prefer learning about wind energy potential. The information which most supports this point comes from the survey question which asked users directly whether they had a preference. Although most did not have a preference, of those that did, 44% preferred learning about wind power while only 8% chose solar power as their favoured source. Obviously, a potential bias may come from the wind portion of the exhibit being made to a higher quality than the solar section. However, great care was taken to design both sections as similarly as possible to eliminate this problem. The only obvious difference between the two sections is colour scheme.

Another source of partiality could come from many users possibly not viewing the solar section at all due to time constraints or other factors. Yet by recalling observations regarding sections visited, one will find that nearly all of the visitors viewed equal amounts of content in both areas. Additionally, respondents who did view the wind section more than the solar section are not great enough in number to create the decisive verdict which the data suggests. A final factor to confirm the above conclusion comes from data collected regarding the user's preferred section of the exhibit. Of all of the sections enjoyed the most, 73% were wind power sections.

5.2.4 Summary of Preferred Exhibit Type

The final objective of the project was to find the manner of interaction with renewable energy information most desirable to the public. The options include an interactive section, a section concerning observation of real-time statistics, and an observation section discussing the long-term potential of the systems. Two questions were used to uncover this information. The first question asked the users which section of the site they most preferred. 80% of the respondents enjoyed the *Virtual Wind* and *Virtual Sun* sections. Such a response heavily favours interactivity as the preferred exhibit format.

To intensify conclusions from the previous question, users were asked which section of the site they preferred least. Although most users opted for nothing to dislike, those who did most often disliked the monthly statistics sections. This can be due both to the staleness of non-real time or interactive data and difficulty in understanding graphical representations. Children in the seven to ten year-old bracket especially did not like this section by observing the age breakdowns for the response to this question and children listing graphs as a source of confusion in Question 3. One can surmise that children have difficulty comparing two variables simultaneously, which graphs require, and that such data types may have not been covered in their schooling as found in background research. To account for this issue, the site should be restated to target seven to fourteen year olds and their families or a slightly older bracket of nine to fourteen year-olds.

6. CONCLUSIONS AND RECCOMMENDATIONS

Various goals were associated with this project and each was completed to satisfaction. The museum desired an exhibit that would not only educate users in the potential performance of renewable energy system that may be soon constructed on the roof of the facility, but stimulate them in the subject matter. The evaluation data indicate that the information selected for presentation effectively informs users in this respect and further suggests that the methods of presentation made the content both informative and intriguing to the target age group. Additional support stems from the survey which suggests nearly all of the users would use the exhibit were they to come across it within the Museum. Hence, the exhibit is presented to the Museum of Science as a document which can easily and effectively function on the Internet and within a gallery kiosk.

In addition to the goals the Museum posed regarding creation of the exhibit, the Team took it upon themselves to address additional issues currently facing the creation of the Energy Gallery. Decisions were not clear as to the renewable energy system to be added to the roof if constraints allowed the production of only one. Additionally, several potential exhibits had been proposed to showcase information from the roof but no evaluation had been performed on which type would be the most successful. By following the same format when making the wind energy section and solar energy section, unbiased data were gathered which indicated wind energy to be the source most preferred by the public to learn about. This preference may result from recent news coverage regarding wind turbine construction as a new large-scale development by the UK, thus making users feel wind energy is more personally applicable than solar. Concerning exhibit types, data suggest that highly interactive exhibits are much more interesting and useful to patrons than the alternative.

From the preliminary data gathered on these two topics, we suggest that future renewable energy exhibits should focus on interactive, wind-based designs. Although not perfect representations of what eventually may occur, the Live Wind and Live Sun sections received a very poor response from users and underscore that mere synthesis of data from the roof is not sufficient enough for a successful exhibit. Should constraints only allow the development of limited number or a single exhibit, those of the suggested characteristics may make museum visitors feel more fulfilled from their Science Museum experience. Again, this data should only be viewed as a preliminary investigation into the topic and further research should be performed before an informed decision is made in this respect.

For an Interactive Qualifying Project to be successful, it must enable students with a further understanding of how their careers as students and professionals impact the social structures they are a part of. Here, through the joint application of skills in the realm of science and research into communication with the public at large, we have produced an instrument for instruction on the topic of renewable energy. By working in tandem with members of the National Museum of Science and Industry, members of the WPI community have learned both the challenges and the benefits inherent within the field of science education.

Bibliography

Anonymous (2000). Europe Commits to Renewable Energy. Power Engineering, 104(7), 78.

Belcher, Michael. (1991). Exhibitions in Museums. Washington: Smithsonian Institution Press.

Boyle, Godfrey. (1996) Renewable Energy. Oxford: The Open University.

Brodie, L., Stunell, A. (1999). Energy: Clean and Green by 2050. Centre for Reform Paper No.12 London: Centre for Reform.

Burke, M. (2000). A Doubling if Renewable Energy Could Brighten the European Union. Environmental Science & Technology, 34(15), A333-A334.

The British Wind Energy Association. (2001). Available at: http://www.britishwindenergy.co.uk. (Accessed: 15 March 2001).

Cole, Nancy. (1995) Renewables are Ready. Vermont: Chelsea Green Publishing Company.

Collinson, A. (1991) Facing the Future: Renewable Energy. London: Evans Brothers Limited.

Domey, L., Kogel, W., and Newton, B. (2000). Science Museum Energy Gallery. Interactive Qualifying Project, D007I. London: WPI Project Centre.

Dresser, T., Jeas, A., Kern, B. and Waloniski, J. (2000). Fuel Cell Exhibit for the National Museum of Science and Industry. Interactive Qualifying Project, E032I. London: WPI Project Centre.

Energy Technologies Support Unit (ETSU). (1994). An Assessment of Renewable Energy for the UK. London: Her Majesty's Stationary Office.

The European Union Renewable Energy Centres (EUREC) Agency. (1996). The Future for Renewable Energy: Prospects and Directions. London: James & James (Science Publishers) Ltd.

European Wind Energy Association. Avaiable at: http://www.ewea.org/. (Accessed: 15 March 2001).

Fenczik, P. et al. (1999). Macromedia FLASH 4: Using Flash. San Francisco: Macromedia Inc.

Fitzgerald, Mark. (2001). PV Power Resource Site. Available at: http://www.pvpower.com. (Accessed: 19 March 2001).

Freris, L.L.. (1990). Wind Energy Conversion Systems. Hertfordshire: Prentice Hall.

Flash Kit- A Flash Developer Resource Site. Available at: http://www.flashkit.com. (Accessed: 22 March 2001).

Gammon, Ben. (2001). Evaluation Training – The National Museum of Science and Industry. London.

Gillett, W., Stainforth, D., and Yordi, B. (1997). The Commission of the European Communities' (EC) Demonstration and THERMIE Programmes for Photovoltaic (PV) Applications. Solar Energy, 59, 59-66.

Goodman, A. (1999) Survey and Questionnaire Development. Available at: http://www.deakin.edu.au/~agoodman/sci101/chap8.html#RTFToC2. (Accessed: January 27, 2001)

Hibbert, L. (1999). Mind the Energy Gap. Professional Engineering, 12(1), 38-39.

Kalton, Graham. (1983). Introduction to Survey Sampling. Beverly Hills: Sage Publications.

Lewis, Ralph H. (1976). Manual for Museums. Washington: National Park Service, 1976.

Long, G. (1978). Solar Energy: its potential contribution within the United Kingdom. London: Her Majesty's Stationary Office.

Musciano, Chuck. (1998). HTML – The Definitive Guide. Sebastopol, CA.: O'Reilly & Associates.

Department for Education and Employment (DEE). (2000). National Curriculum Online. http://www.nc.uk.net/home.html (Accessed: February 2, 2001)

The National Museum of Science and Industry. (2000). National Museum of Science and Industry. http://www.nmsi.ac.uk/ (Accessed: January 23, 2000)

Neal, Arminta. (1973). HELP! for the Small Museum. Boulder, Colorado: Pruett Publishing.

Oy Windside Production Ldt. Instruction and Operational Manual for Windside Wind Turbines. Pyhasalmi, Finland: 2001.

Righter, Robert W.. (1996). Wind Energy in America. U.S.A: University of Oklahoma Press.

Roberts, Lisa C. (1997). From Knowledge to Narrative – Educators and the Changing Museum. Washington: Smithsonian Institution Press.

Shneiderman, Ben. (1998). Designing the User Interface: Strategies for Effective Human-Computer Interaction - 3rd ed. Reading, Massachusetts: Addison-Wesley, 1998.

Simpson, B. (1991). Earthkeeper. March/April, 1991

Spiewak, Irving. (2000). Solar Thermal Energy Technology: Potential for a Major European Industry. http://www.jrc.es/iptsreport/vol10/english/Ene1E106.htm (Accessed: January 27, 2001)

Wyman, V. (1993). All Fired Up for Renewable Energy. The Engineer (London, England), 227, 22.

Current Links in Exhibit

http://www.britishwindenergy.co.uk

http://www.thetimes.co.uk/article/0,,2-110414,00.html

http://www.thetimes.co.uk/article/0,,37-110548,00.html

Appendix A – The National Museum of Science & Industry

Mission Statement

"The Museum exists to promote the public's understanding of the history and contemporary practice of science, medicine, technology and industry." (Dresser et al., 2000, p.79).

Background Information

The Great Exhibition of 1851, organised by Prince Albert, promoted scientific achievements (Dresser et al., 2000, p.79). The profits from this successful Exhibition were used to establish the South Kensington Museum in 1857. The Science Museum was formally separated form the Victoria & Albert Museum in 1909.

The National Museum of Science & Industry is comprised of three museums, the Science Museum, the National Railway Museum in York and the National Museum of Photography, Film & Television in Bradford (The National Museum of Science and Industry (NMSI), 2000). Funded by grant-in-aid from the Department of Culture, Media and Sport, the Museum is directed by a Board of Trustees appointed by the Prime Minister.

The world's largest and most significant collection illustrating the history and contemporary practice of science, technology, medicine and industry is possessed by the National Museum of Science & Industry (NMSI, 2000). There are more that 40 individual galleries contained within the seven floors of the Science Museum. Showcased in these galleries are over 15,000 objects from the Museum's collections.

Appendix B – Summarised Notes from an Interview with James Hanlan

This appendix includes information gained from Professor James Hanlan, a history professor at Worcester Polytechnic Institute, Worcester, Massachusetts. The information is paraphrased from the original notes from the interview.

Elizabeth Hart and Joseph Knuble conducted this interview on February 13, 2001 at Worcester Polytechnic Institute.

How much does hands on learning improve the quality of an exhibit?
In the United States museums that contain hands on exhibits receive an international reputation because of it. Industries also give more funding to notable museums such as these. Interactivity is essential at the Museum of Science and Industry in Chicago, Illinois.

What considerations should be made when making a web based exhibit?
Web exhibits are the best when they serve as a preview for the real exhibit. Mystic Seaport Museum had a virtual tour of certain exhibits on their website. So far this has worked very well in giving a preview for the museum and had not taken away from the actual exhibit itself.

Are web exhibits a good approximation for real exhibits?
Yes, if done correctly they should portray what the actual exhibit will be.

How do you evaluate interest in an exhibit?
Surveys and questionnaires are good ways to start to get an idea of how effective an exhibit is. Professor Hanlan says the public in London is very responsive to foreigners (Americans), so interactive questionnaires may be a good way for us to obtain feedback about our exhibit. Professor Hanlan also told us that evaluating interest in a particular subject could be difficult to achieve. An entire IQP could revolve around that.

What considerations should be made when designing exhibits for a 7-14 year old audiences?
The exhibit should be engaging, while also enabling people to understand it at a glance. It is also important not to speak down to the audience, while at the same time not using language that is too technical. Professor Hanlan suggested that we look at junior high school material to get a sense of appropriate terminology.

Appendix C – Summarised Notes from an Interview with Matthew Straumpf

This appendix contains information that was gained from an interview with Matthew Straumpf at the Boston Museum of Science on Februrary 15, 2001. Elizabeth Hart, Joseph Knuble and David Tolmie were all present for this interview.

To determine the effectiveness of the computer exhibits we found it most helpful to talk to the Conners Computer Place Fellow who managed the exhibit. Mathew Straumpf gave us valuable insight into the set-up and implementation of the computer cluster. He stated that the software selected for the computers is not directed simply towards a specific age group of children, but more for children and their families. Mr. Straumpf selected commercial software which he found to be interactive, informative and avoided mundane interactivity such as simple quizzes. Ease of use was also a primary concern.

The museum does not conduct formal surveys or employ monitoring software to find how effective their web exhibits are. Data in this respect is essentially gathered from the general observations of museum employees. Mr. Straumpf felt our idea of incorporating monitoring software into the computer exhibits was a good idea and one he may potentially employ.

Further issues he felt were important in computer exhibit design were using large typeface for the visually impaired, adding audio where applicable and using trackballs for the computer interface. An additional issue he brought up which we had not considered is security. Specifically, keeping users within the web exhibit and only the links provided from the exhibit.

Appendix D - Preliminary Evaluation Questionnaire for Museum Staff

1. What did you think the exhibit was trying to show?

2. What are your feelings on how the information was presented?

3. Were there any terms or phrases in the exhibit that may be difficult to read or understand?

4. What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?

5. Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.

6. Do you think children would find this site interesting?

Appendix E – Summarised Notes from Interviews with Museum Staff

The following are summarised notes from interviews with Museum staff that occurred on 03/28/01-04/02/01. The interviewee was asked to go through the wind portion of the site and make any comments as necessary. A series of follow up questions were asked to each individual after they were done exploring the site. Present at these interviews were Elizabeth Hart, Joseph Knuble and David Tolmie.

03/28/01 1:00: Owain Davies – Exhibition Developer

Wind Menu Observations

Upon reaching the Wind Menu, Mr. Davies felt too much information was presented at once. The menu should also be better defined as a menu. "Click below to see me blow" was not a clear enough reference. The sentence descriptors for the different sections were also too wordy and should be broken up into different sentences.

Virtual Wind Observations

Here Mr. Davies felt the concept of the wind slider was a little difficult to understand and should have better directions. The word "slider" may also be unfamiliar to some people and should be given a more general name. He felt the content of this section was also too busy. The amount of information given at once was too great and could confuse the user. Perhaps a delay should be added which made the factual paragraph appear at a later point when using the interactive section.

Live Wind Coverage Observations

Live wind coverage should place further emphasis on the fact that the wind speed shown is actually live. People might think the speed shown is generic and not actually real-time. The descriptor for that speed should be changed to alleviate this problem. Also, the text stating that turbines in urban environments can provide useful power is an obvious statement given the live data, and makes the page too busy. The paragraph should be removed.

Yearly Output Statistics Observations

The text shown in the yellow flash at the top right of the screen is not clear. "Global wind power potential" would be confusing to people and should be re-worded. The graphs showing power output for a turbine along with the yearly power demand for the UK are too close together and could cause confusion. They should be separated and more individualised. Mr. Davies felt the fact referring to turbine's paying back the energy used in their construction within 3-5 years was not very useful and cluttered the page. Besides what he liked about the page, he felt again there was simply too much information given at once.

EVALUATION QUESTIONS

1. **What did you think the exhibit was trying to show?**
   The potential use of renewable energy systems through wind. He felt our information focused on the possibility for the future.

2. **What are your feelings on how the information was presented?**
   Often the content was too busy and overwhelming.

3. **Were there any terms or phrases in the exhibit that may be difficult to read or understand?**
   The statement regarding global wind potential and the wind slider were difficult to understand.

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   No changes. He felt the introduction was fine.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.**
   Perhaps the slider bar should have hash marks or some indicator of the different behaviours of the turbine in certain wind speed ranges.

6. **Do you think children would find this site interesting?**
   Yes. He felt the site was very fun and colourful.

03/28/01 2:15: Peter Davison - Project Co-ordinator of the Energy Gallery

Wind Menu Observations

Mr. Davison thought that it was distracting that *Mr. Wind's* animation overlapped the opening text when he first entered the wind section. He suggested that we might want to slow down the animation so that it is not as distracting. Perhaps *Mr. Wind's* movement should be farther away from the text.

Virtual Wind Observations

When entering the virtual wind section of the site Mr. Davison thought that the page was laid out in a very clear and informative manner. He also thought that the interaction within this page was very exciting and fun. The only suggestion that he had is that we might want to compare more household appliances along with televisions and light bulbs.

Live Wind Coverage Observations

The only suggestion that Mr. Davison had with this section was where to superimpose the actual wind turbine in our photo of the roof that is displayed on this page. He also gave us a little insight into the type of wind turbine that museum was thinking of using.

Yearly Output Statistics Observations

Mr. Davison felt that there was a lot of information trying to be conveyed on this page. He thought that the information in this section was good, but the overall page was to busy. He suggested to maybe having the different pieces of information to pop up or appear at different times, so that the user is not overwhelmed.

EVALUATION QUESTIONS

1. **What did you think the exhibit was trying to show?**
   The potential of solar and wind power and factors relating to these technologies.

2. **What are your feelings on how the information was presented?**
   The information was presented colourful, fun, and organised manner. It was a little bit too busy on the yearly output page.

3. **Where there any terms or phrases in the exhibit that may be difficult to read or understand?**
   He did not think that there were any terms or phrases that where difficult to understand. He thought that we could shorten the phrase on the type of turbine we used in the virtual wind section. He also suggested that we make sure through wording that in the live wind section that people new that the wind speed was of that day and not just a random number selected.

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   He thought that Buckingham palace was to dominate on the opening page because it was so well defined over that other buildings. He suggested taking out the windows to avoid having it to dominate. He thought that we should change the animation of the sun to a more realistic path for the sun to follow. He would like the building that we portrayed as the museum to be more defined or detailed. He thought that the panels of the solar array blended into the background too much. He finally suggested that we have people laying down and then when the city comes to life have them start running around.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.**
   He would like to see somewhere on the sight to show where wind energy is used throughout the world. He would also like to see a map showing the existing wind farms in the UK.

6. **Do you think children would find this site interesting?**
   He believed that the web page would be interesting to kids and he thought that adding sounds would enhance their interest.

03/29/01 11:00: Nicky Lewis – Exhibition Developer

Wind Menu Observations

Ms. Lewis felt that the first fact on the wind page was a bit much and suggested splitting up the text. She also felt the yearly output link should make some mention to the environmental facts that it contained.

Virtual Wind Observations

A lot of time was spent on this page by Ms. Lewis. Her first comment was about the text that accompanied the changing wind speed. She felt that using the word "cube" to explain the wind speed was unnecessary and could be confusing to children. Suggestions were also made about putting in some text to try to get the user to want to continue increasing the wind speed. It was also a little unclear to her how far the slider would allow a user to go. While using the site, Ms Lewis noticed that she didn't find herself looking at the televisions and light bulbs. She suggested that we somehow tie together the spinning turbine with the televisions and light bulbs, some way to draw the attention over to that screen. A colour change of the instructions was also recommended to lure the user to vary the wind speed to its full potential.

Live Wind Coverage Observations

Minor comments were made in regards to this portion of the site. It was suggested that the yellow box with text pop up either after the site had loaded or by pressing a button inciting the user to bring up the text as an answer to a question. Also the text in this box was slightly difficult to read, it was suggested that it be changed. Ms. Lewis also felt that it might be a good idea to highlight some of the technical terms so the user could click on them and gain more information if the term was unclear to them.

Yearly Output Statistics Observations

This page was overwhelmed with facts. Ms. Lewis again suggested splitting up the facts, bringing them up at different times, and also the possibility of having a separate link to the pollution statistics. She felt that they were all very good facts, but that more would be gained from them if presented differently. The graphs that are going to appear on the page were also a place for improvement. These could be boring to some users, so it was suggested to have some way to make them more active, possibly by having the graphs load as the page loads.

EVALUATION QUESTIONS

1. **What did you think the exhibit was trying to show?**
   Ms. Lewis felt the site showed an overview of wind energy and how it is and could be used in the UK.

2. **What are your feelings on how the information was presented?**
   The graphics were very good, but Ms. Lewis felt that there was too much on one page.

3. **Were there any terms or phrases in the exhibit that may be difficult to read or understand?**
   Terms found by Ms. Lewis to be difficult to understand were "cube" and "tubular". Cube was recommended to be left out, and a possible glossary link for tubular. The text in the yellow box on the live wind coverage page was suggested that it be changed.

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   The beginning of the opening was dark. Ms. Lewis also pointed out that a lot of users would want to click on the question to arrive at the answer, instead of clicking on the text at the bottom corner of the page, which took her a little bit to find. She also suggested that the renewable energy systems rise up as *Ms. Sun* and *Mr. Wind* appear on the page, in order to draw attention to them.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions that you may have on ways to improve it.**
   Ms. Lewis suggested that we make some indication on the slider bar so that it is clear how far the user can go and to get them to want to take the wind speed to the next level.

6. **Do you think children would find this site interesting?**
   Yes. Children will relate to this information through the characters and graphics. Ms. Lewis feels our challenge will be getting the technical information across to the user.

04/02/01 1:30: Alan Morton – Senior Coordinator Modern Physics (Liason to Renewable Energy Team)

Dr. Morton's desired a section describing current trends in the harnessing of wind energy. He mentioned that 60% of the wind potential in Europe lies within Britain, yet Denmark leads Europe in using wind power. Perhaps information should be included about the use of offshore wind farms and research into larger turbines.

EVALUATION QUESTIONS

1. **What did you think the exhibit was trying to show?**
   The potential for wind energy and the Science Museum in general.

2. **What are your feelings on the how the information was presented?**
   The information of the highest priority in the site is not clear. A mention of pollution prevention is made on the opening menu but only a small section of the site deals with pollution.

3. **Were there any terms or phrases in the exhibit that may be difficult to read or understand?**
   Generally, children are taught velocity through the metric system so meters per second should be used instead of miles per hour.

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   In the introduction page the question "Does the UK have a future in energy" was misleading. Perhaps "What is the future of energy in the UK?" should be used.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.**
   Yes, it was fine.

6. **Do you think children would find this site interesting?**
   Yes.

04/02/01 1:30: Emma Freeman – Exhibit Developer

Emma felt that generally too much information was displayed on each page. It should be broken up maybe using pop-up menus.

EVALUATION QUESTIONS

1. **What did you think the exhibit was trying to show?**
   Beneficial ways to reduce consumption and more.

2. **What are your feelings on the how the information was presented?**
   The information was user friendly.

3. **Were there any terms or phrases in the exhibit that may be difficult to read or understand?**
   "Photovoltaic" was a tongue twister.

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   The correlation between the town being dark and there being little energy was slightly unclear.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.**
   Moving the slider was somewhat difficult. Also there seems to be too many things to observe at one time. Perhaps colours should be changed to better direct the eye.

6. **Do you think children would find this site interesting?**
   The site is fine for fourteen-year-olds, but seven-year-olds will have a harder time with it.

04/02/01 1:30: Sophie Duncan – Exhibit Developer

Sophie felt that there was too much information displayed on the yearly potential section.

<u>**EVALUATION QUESTIONS**</u>

1. **What did you think the exhibit was trying to show?**
   How effective are wind and solar energy.

2. **What are your feelings on the how the information was presented?**
   Liked the design, but it was a lot of information to take in. She suggested that the links on the wind menu should be delayed when you first enter the section.

3. **Were there any terms or phrases in the exhibit that may be difficult to read or understand?**
   No

4. **What was your initial reaction to the introduction page? Is there anything that you would consider adding/taking away?**
   Change the opening question, so that it is more understandable.

5. **Was the interactive portion easy to understand and use? Please tell us any suggestions you may have on ways to improve it.**
   In the virtual wind section, have a better visual connection between the slider bar and turbine with the television and light bulb outputs.

6. **Do you think children would find this site interesting?**
   The site is fine for eleven to fourteen year olds for text, might need to be more basic for seven to ten year olds.

Appendix F – Observation Sheet and Feedback Survey

Hello my name is …. and I work for the Science Museum. We are testing an exhibit for a new gallery that we are developing. Would you and your child(ren) be interested in spending a few minutes helping us test it out? {if yes take them to the testing area}. This is only a prototype for 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 that you came across it in gallery….

Specific points to look out for:	Describe step by step what happens as if you were dictating out loud to someone
How do the users react to the opening animation?	…………………………………………………………
What do the users say to each other and you?	…………………………………………………………
In what order do the users go through the exhibit, how far did they go, and how long did they view each section?	…………………………………………………………
Do the users appear to understand the buttons and links?	…………………………………………………………
Do the users appear to read the exhibit content?	…………………………………………………………
Do the users read the interactive facts? Did they just flash by them?	…………………………………………………………

Additional Observations:

Follow Up Questions:

1. What do you think this exhibit was trying to show you? {Prompt with "What do you think we are trying to tell you about energy?" if they are stuck.}

2. Did you find the information that was in the exhibit interesting? {if yes, what}

3. Were there any words or sections in the exhibit that you found confusing? {was there any text that was too long, any text hard to read, colour issues}

4. Did you like the characters *Ms. Sun* and *Mr. Wind*? {if yes, did you like one better?}

5. What did you like the most about the exhibit? {Probe with what section or ask for more details if an answer that is too general}

6. What did you like the least about the exhibit? {Probe with what section or ask for more details if answer is too general}

7. Did you have a preference for learning about wind power or solar power?

8. If you saw this exhibit in the Museum, would you use it?
   Definitely Not – Probably Not – Maybe – Probably – Definitely Yes

9. How clear was the use of televisions to show amounts of power?
   Very Confusing – Confusing – Clear – Very Clear

Age Group:
<7 7-10 11-14 15-18 19-35 36-50
>50
M/F

Date:

Appendix G – Design Process: Creative and Content Decisions

As learned from background research, the exhibit should satisfy several design factors. Generally, the site must be clear, organised and engaging in manner. Content should be intriguing enough so the individual desires further interaction with the exhibit. Criteria the exhibit must emulate include interactivity, clarity and conciseness of data, appropriateness for target audiences, coverage of necessary information, and reality of construction in the given time constraints.

The Team devised three methods were devised which were felt to properly showcase the essential aspects of renewable energy potential. Not only did they cover the necessary data, but presented it in a fashion to allow users to easily grasp difficult concepts. Care was taken to not weigh users down with technical background on the technologies as that was not the focus of the project.

How environmental conditions affect the outputs of renewable energy systems, often their greatest limitation, was decided to be a key concept in understanding the potential of the systems. A high level of interactivity was chosen as the best method to educate users in this respect as a great degree of technical information must be conveyed. The *Virtual Wind* and *Virtual Sun* sections are the realisation of this concept. Additionally, having a real-time and more personalised interaction with a concept also aids in understanding and appreciating it; this was accomplished by simulating the power a wind turbine and solar array would produce were they to exist on the Museum roof. From this users, will gain a better appreciation for how renewable energies even close at hand can be usefully harnessed. *Live Sun Coverage* and *Live Wind Coverage* satisfy this and also satisfy the desire for the Museum to simulate such systems which they might actually install in the future. Additionally, these sections could be evaluated to assess visitor interest in what soon may be realised in the Museum. The decision was also made that the public must understand the long-term benefits and limitations to the technologies to better understand their potential use in the UK. *Monthly Power Potential* shows both how the different systems perform during the year and how they affect the communities which employ them. Finally, in order to give users the opportunity to explore wind power beyond our site, a section entitled *Wind Links* was added which contain useful links to web sites hosting different discussions.

Once the content had been established, the method of communication for each was determined. In order to make the content appealing to children, great care was taken in the graphic design of the site. All graphics were made from scratch and throughout the site; links were made large and clear, with effort placed on avoiding placing too much or too little content on each screen. Bright, pastel colours were employed and balanced throughout the site to add visual appeal while avoiding confusing the eye. Generally, a cartoon-like visual theme was used throughout the site. To assist navigation, each section of the site was given its own colour scheme to aid users in understanding their current location in the site and to recognise the different sections of the exhibit. For general understanding and familiarity, the solar section was made using warm colours while the wind section was made mostly with cool colours. Backgrounds for each section were made to be gradations of colour with a darker or brighter colour at the centre which faded into a more neutral colour at the extremes of the screen. This is a technique often employed in graphic design as it focuses the attention of the user more to the central content.

Developing the text and facts for the site was structured so that they could be easily understood while still informative and interesting to the target viewing audience. Considerations were made regarding word selection and interpretation of the presented information. Choosing appropriate words to present the information was important to relate to the audience. If words were used too complex for users to understand, this could turn users away from the site. On the other hand, words below the level of the users could make them feel that the site was below them, and not want to use it. Additionally, background research along with discussions with Museum personnel, suggested that the longer a portion of text on an exhibit, the less likely users are to read it. After writing each paragraph, efforts were made to shorten the statement either through removing parts of the fact or finding a shorter way of expressing it. A fun, kid-like font was used in the site for titles and very brief facts. Paragraphs which contained longer, more complicated information used a typical print font to increase their clarity.

Navigation was also given careful consideration in the exhibit. Different sections of the exhibit were carefully labelled at all times to allow users to understand what they are studying and where they are within the site. Each section was labeled "Wind Energy" or "Solar Energy" respectively, and the title for the section placed in a larger font below this. In the lower right portion of each section a menu was supplied to allow users to return the main section menu, move to the menu for the other energy source, or return to the home page, where solar or wind energy is first selected. Such a simple and useful navigation helps users to move where they wish in the exhibit quickly and with little confusion. The navigation buttons were left the same shape and colour throughout the exhibit for consistency and to allow the menus to be quickly recognised wherever users might be.

An essential and difficult concept found throughout the site is that of electrical power. Obviously, the watt is a unit beyond the comprehension of most young people. Varying amounts of televisions and light bulbs were employed as quantifiers of power. These were both selected as they are electrical appliances of great familiarity to most children. The decision to use both appliances was made to enhance comprehension of the concept through comparison. However, the amount of watts generated by the systems was still incorporated, although de-emphasized, for the curious adult.

G-1 – Opening Animation and Main Menu

The opening animation for the web site was created in order to draw an initial spark of interest in visitors for the exhibit. This was found to be an essential element of successful exhibits after performing background research and visits to the Boston Museum of Science. The theme of our method for attaining initial interest is to instill anxiety regarding Britain's future in energy production and consumption. The opening screen first poses the question "What is the Future of Energy in the UK?" in a dreary font with a drawing of London below. The city is dark and drab (perhaps from lacking clean, renewable energy) to match the previous title question which makes for quite a foreboding scene.

In the lower left portion of a screen, a statement reads, "Click here for the answer." Clicking this statement initiates an animation which brings users into the main portion of the site. Mr. Wind and Ms. Sun fly onto the screen along with a solar panel and a wind turbine. The screen flashes to life, seemingly from the new-found energy sources, and users are brought to the home page of the exhibit.

Here *Mr. Wind* and *Ms. Sun* take position in the top corners of the screen along with their now functioning energy systems. The energy from the characters makes the turbine spin and the solar array reflect bright light. All of the colours of the scene are made more bright and vibrant to reflect great hope in Britain's energy future. The city too has been changed to be more full of life, cheery and animated.

"Renewable Energy Potential" replaces the question of the opening screen. The different energy systems are clearly labeled as buttons to allow users to enter their respective sections. Additionally, *Mr. Wind* and *Ms. Sun* are made clickable in case users interpret them as menu options.

G-2 – Wind Energy Section

G-2.1 – Wind Menu

Once users click on the turbine or *Mr. Wind* from the main menu, they are brought to the wind menu. The page opens with *Mr. Wind* flying onto the screen to give extra dynamism to the page. First, the menu of the four sections of the wind energy area are shown. Shortly, a fact giving a general introduction to wind power fades in at the top of the screen. The fact was brought in later so eyes of the users were not confused by having too much content on the screen at once. In conjunction, a photograph of a wind-turbine is shown to give users a visual grasp of the technology presented.

Each button of the wind menu is large and clearly identified. Different colour schemes are given to each button to add to their individual distinction. The title of each section is shown and a short sentence describing the section is given on the button itself. Additionally, a small graphic depicting the topic covered in the section is added to enhance the overall visual appeal of the screen. Mr. Wind is used on the page to invite users to click on any of the sections they wish to view. The character is also used within each section to give the user a description of the current screen.

G-2.2 – Virtual Wind

This interactive section allows users to vary wind speeds and observe how they effect the output performance of a typical wind turbine. The screen is visually divided into three sections. The left portion of the screen contains a slider for adjusting the speed, the middle of the screen shows the rotating turbine and text describing its current status, and the right portion displays the power output from the turbine in the amount of televisions and light-bulbs powered. Note that people often read content in a left to right fashion. Thus the sections were organised in this chronological, cause and effect manner to allow greater comprehension of the topic presented.

By clicking and dragging on the red button of the slider bar, users vary the wind speed which is shown below in miles-per-hour (mph). The slider is clearly labelled as such and instructions are provided for using it. Miles-per-hour are used as a wind velocity as this unit is what is employed for wind-speeds in weather forecasts. Additionally, mph is used to quantify automobile speeds in the UK and thus makes a familiar reference. When using the slider, lines indicating wind strength from *Mr. Wind's* lips grow and shrink respectively. This gives users a good understanding of just how powerful the winds are which they produce. Finally, the slider bar is labelled with a "Start" and "Finish" to invite users to explore the different extremes of wind they can produce.

The wind turbine faces *Mr. Wind* and changes rotation speed based on the current wind velocity. Below the turbine, changing facts describe the different states the wind turbine functions within. It is important for users to understand how different wind-speed ranges effect turbines in different ways. As a valid product of the Museum of Science, great care was taken to accurately portray the power potential for each renewable energy system.

For wind speeds below 8 mph, a fact states that more wind is needed to make the turbine begin rotation. For speeds between 8 mph and 31 mph, a paragraph that power increases with the cube of the wind speed is shown. The general formula for power from a horizontal axis wind turbine was used:

$$P = \tfrac{1}{2} pAV^3$$

Where p is the efficiency of a typical turbine, A is the swept area of the blades, and V is the velocity of the wind. Research showed that p was often 0.266 and was used in the calculation. Typical blade lengths (L) of 13.5m were used to find the swept area where:

$$A = \pi L^2$$

V is measured in meters per second for this equation and is set by the user from the slide bar. For wind-speeds between 32 mph and 56 mph, the turbine is described to be producing a constant and maximum amount of power. This maximum output for the turbine modelled here is 225kW. The televisions used are rated at 100W and the light bulbs are 60W. For speeds greater than this, a fact tells that the wind speed is dangerous for the turbine and it must be shut down. The drawing of the turbine stops rotating at this speed. The description paragraphs for each wind-speed range were minimised in size as there are several of these paragraphs and together could be too much information to read at once.

Again, the power output section displays the number of televisions or light-bulbs which could be powered by the current wind-speed along with the power level in kilowatts. The section is titled with "You are powering…" to place emphasis on what the action of the individual users are producing. All of the power outputs are grouped into a blue box to clearly demonstrate that they are connected. A power cord also runs from the blue box to the turbine to demonstrate that the power is coming directly from the turbine.

Ten seconds after the page has loaded, allowing time for the eye to adjust to the previous content, a fact describing the dimensions of the turbine flies onto screen. This fact gives users an understanding of the size of the turbine simulated in the section and an understanding of how different sized turbines produce differing amounts of power.

G-2.3 – Live Wind Coverage

This section employed a Java program which retrieved the current wind-speeds for London from:

http://www.cnn.com/WEATHER/eu/England/LondonEGLL.html

and calculated the corresponding amount of power a turbine could generate from this speed. The turbine modelled mimics the Windside vertical-axis WS-4C turbine and its battery-charging system. The Museum is currently investigating this device for purchase and construction on the roof of the facility.

To enhance the feel of the winds above the Museum being the actual source of power, photographs were taken of the roof and images of the WS-4C were superimposed on it with a photo-editing program. Museum staff were consulted on the exact portion of the roof where the turbine is to be added and its exact position. This accuracy was useful in justifying the Live Wind Coverage section as a viable simulation of the soon-to-come roof station for both visitors and curious Museum staff. The photo was displayed largely to aid visitors in understanding what it represented. To clarify the unique technical nature of this turbine, an enlarged version was placed on the page along with large arrows to demonstrate how it rotated. The characteristics and justifications for using such a strange turbine are stated in a short paragraph just below the main photograph.

Once the Flash program attains the wind-speed from the Java program, (full details of the Java program used can be found in Appendix H) resulting power calculations are performed and displayed. Three main parts compose the power output section on the right half of the screen. The section was designed using the same blue of the output section in Virtual Wind for consistency and recognition. Each section represents a cause and effect connection of first showing the wind-speed, then the power the turbine would generate from this wind speed, and finally the amount of televisions this power could enable. To emphasise this cause and effect relationship, each portion is given its own blue box with an arrow passing from itself to the next box. The arrows also give the user the correct impression of where they should first look on the screen. Numerical statistics in each box were given separate highlighting with a different coloured box and larger font to stress their connection.

The first and top portion of the area states that "The wind speed on the roof today is X mph…" Consideration was made when designing this sentence to properly emphasise that the wind speed shown is indeed live and not static. The second section is labeled "Making our turbine generate X watts…," which is a continuation of the first statement. The third section states "Which could power X T.V.s". The content for the boxes was made as a continuous thought to allow the user to better understand how to progress through them. A television is placed on the bottom section to emphasise the final result of the power gained from the wind.

G-2.4 – Monthly Power Potential

The monthly power potential section educates users on the long term performance of wind turbines in the UK. On the opening screen, a graph displays how typical wind speeds vary throughout the year. Immediately below this, the corresponding amount of power a turbine would generate from this speed is shown.

The graphs are clearly labelled and units are made large and clear. Additionally, each graph was given its own colour scheme to further distinguish them. A fact is shown in the top right corner of the screen which discusses the world-wide potential of wind power. A yellow flash surrounds it to distinguish the fact from the rest of the content.

Users may wonder what this power would be useful for, now that they can easily observe the performance of wind turbines during the year. A large button below the graphs has a label of "What could we do with this power?" This question is made with a purple colour scheme with a lower portion labelled "Click Me" set in yellow. The colours are made compliments to emphasise that the graphic is indeed a clickable button. Clicking this button will superimpose new content related to this question on the same screen. The information was made accessible through a button to break up the content of the screen and reduce the busyness of the presentation.

Once clicked, a second graph appears below the two previous which displays the varying power demand in the UK throughout the year. Peak wind power and peak UK demand occur near the same time of year and an orange circle encloses both of these peaks. A line leads eyes of the users from the circle to a short fact which suggests that this power from the wind could be used help the UK avoid an energy crisis similar to the one which occurred in California. Part of the process for learning about the potential of a technology is not simply what it can do on its own, but how it is beneficial to society.

Similarly, a button on the right of the screen asks, "How much pollution do we avoid in a year?" A major benefit from wind power is its cleanliness. Clicking this button displays statistics about how much pollution is prevented by both one turbine and all 900 turbines in the UK operating in unison. Numerical characteristics such as amounts of CO_2 prevented are offset in their own blue boxes along with how this particular pollutant effects the environment. To quantify just how useful the clean power from these turbines is, a fact concludes the section by stating that all the turbines in the UK could power 259,538 homes.

G-2.5 - Wind Links

Here users are provided links to other web sites dealing with wind power. Offshore wind farms are currently a hot topic in the UK, thus links are provided to articles which are both in favour and against such wind farms. An additional link brings users to a general site discussing wind power in the UK. Each link is set at distance from the next and in a different colour scheme. Descriptions of the linked pages are clear and brief. The system is set up so a new browser window will appear to contain the new page. This leaves the user the option of returning to the exhibit when they desire. If the new page were loaded in the same screen and the user attempted to use the "Back" button, it would simply reload the exhibit from the first opening screen.

G-3 – Solar Energy Section

The solar energy section was designed in a manner identical to that of the wind section. There are three main sections each dealing with the same topics in a similar method of presentation. Design was similar between the two sections to allow unbiased comparisons and evaluations about which was more interesting to the public. Therefore, some topics have been eliminated from the following sections which are repetitions of information. Refer to the Wind Energy Section for coverage of these issues.

G-3.1 – Solar Energy Menu

As with the wind menu, the solar menu is laid out as three main clickable sections each with a description of its respective section and graphic which emulates the data within. A fact generally describing the harnessing solar energy appears after delay along with a photograph of a photovoltaic array.

G-3.2 – Virtual Sun

This section has a similar set up and theme to *Virtual Wind* section. Here users adjust a slide bar to change the size of a solar array while the corresponding characteristics and power output of the array are shown. Again, instructions are clear and content is concise. When moving the button of the slide bar, the length of the sides of the array are shown. The array is defined as a square array so the area, which is the main variable in power output, can be adjusted by simply modifying one side. Adjusting area directly was considered, but children may be unfamiliar with the units of square meters and confused by what they were changing.

The drawing of the array grows and shrinks corresponding to the position of the slider button. Below the array various descriptions are used to educate the user on significant arrays of the current size. Arrays less than three meters are described as being useful for small electrical items such as street lights, remote telephones and calculators. Arrays between four meters and thirty meters are described as being large enough to power a typical British home. Arrays between thirty meters and the maximum of seventy-six meters in length are of a size great enough to be considered solar power plants and can power several houses up to a small village. Wattage is calculated using the general formula for solar arrays which states that one kilowatt is generated for every $10m^2$ of array material. Power outputs are displayed through televisions and light bulbs in the same manner as the *Virtual Wind* section.

Great consideration was put into what users would be allowed to modify in this section. Although array size was finally chosen, many other factors influence output of such systems including tilt angle of the array, the time of day, the time of year, weather conditions, temperature, and photovoltaic material. Although theoretically the user could be allowed to modify all of these, changing one variable of a scientifically accurate system and calculating various power conversions on the fly already pushes Macromedia Flash to the limits of its capabilities. Thus, adding more adjustments makes the behind the scenes programming extraordinarily complicated. Informing the user of these various factors is still important and thus they were added into a small paragraph which flies onto the screen after a short delay.

Varying size of arrays was chosen as the main interactive method because it not only gave users a feel for how much power per square meter an array can produce but also educated users on the different applications of arrays based on their different sizes. Also, this factor had the most impressive effect on power factors making the section all the more interesting. Weather conditions were also considered but little to no data existed on the varying performance due to cloud cover. Thus such little information could not fulfil the large range of values a slide bar offers the user to select.

Cloud cover is a major limitation to solar energy in the UK and must be incorporated somehow. Luckily, research showed that cloud cover generally reduced performance by one quarter. A large button was added to the screen labelled "Make it cloudy!" which when clicked added drawings of clouds between Ms. Sun and the array and also reduced power output accordingly. The paragraph describing the different factors affecting array output changes to discuss how the clouds effect performance. The label of the button then changes to "Make it sunny!" which removes the cloud cover when clicked.

G-3.3 – Live Sun Coverage

This section uses a program similar to that of the *Live Wind Coverage* section. The program retrieves the current cloud conditions in London from a weather web site and corresponding amounts of power an array could generate are displayed. The array simulated has the same characteristics of the array which the Museum may soon install on the roof. Again, a photograph of the roof has an array superimposed upon it in the same position the actual array may soon occupy. A fact below the picture describes the size of the array and mentions when the array produces maximum power. Both facts assist in making the simulation more tangible to the user. In the power output portion of the screen, the weather is described as either "Sunny" or "Cloudy." Kilowatts generated and televisions powered are displayed in a manner similar to the method used in the *Live Wind Coverage* section.

G-3.4 – Monthly Power Potential

Here the number of hours of sunshine the UK receives throughout the year is displayed. The corresponding amount of power a typical array would generate is shown below this. By observing this data, users will understand that solar arrays will perform well in UK's summer months, but poorly during the winter. A paragraph below the graphs expresses this point. Hence users might wonder if this performance can be improved. A large button similar to those found in the *Monthly Power Potential* section for wind energy asks "How will this improve?" and provides a solution when clicked. Through research, efficiencies of solar arrays are expected to triple by 2030 and this fact is showcased in this area. A graph replaces the button titled "Maximum Power From our Solar Array." The graph shows bars reflecting increasing amounts of power from the array over a series of years up to 2030. The bars steadily shift in hue from red to yellow to add the emphasis of increasing intensity. If the graph is not clear to users, a brief paragraph adjacent to the graph summarises the main point. A final portion of the page contains a fact which appears after delay which describes how global solar power potential relates to energy stored in our remaining fossil fuels. All three portions of the Monthly Power Potential page give users both a current understanding of solar power potential and where it may be in the future.

Appendix H – Java Weather Monitoring Program

The following Java program was written for use in the *Live Wind* and *Live Sun* portions of the exhibit. The program is executed upon the first use of the web site and retrieves current weather conditions and wind speeds in London from:

http://www.cnn.com/WEATHER/eu/England/LondonEGLL.html

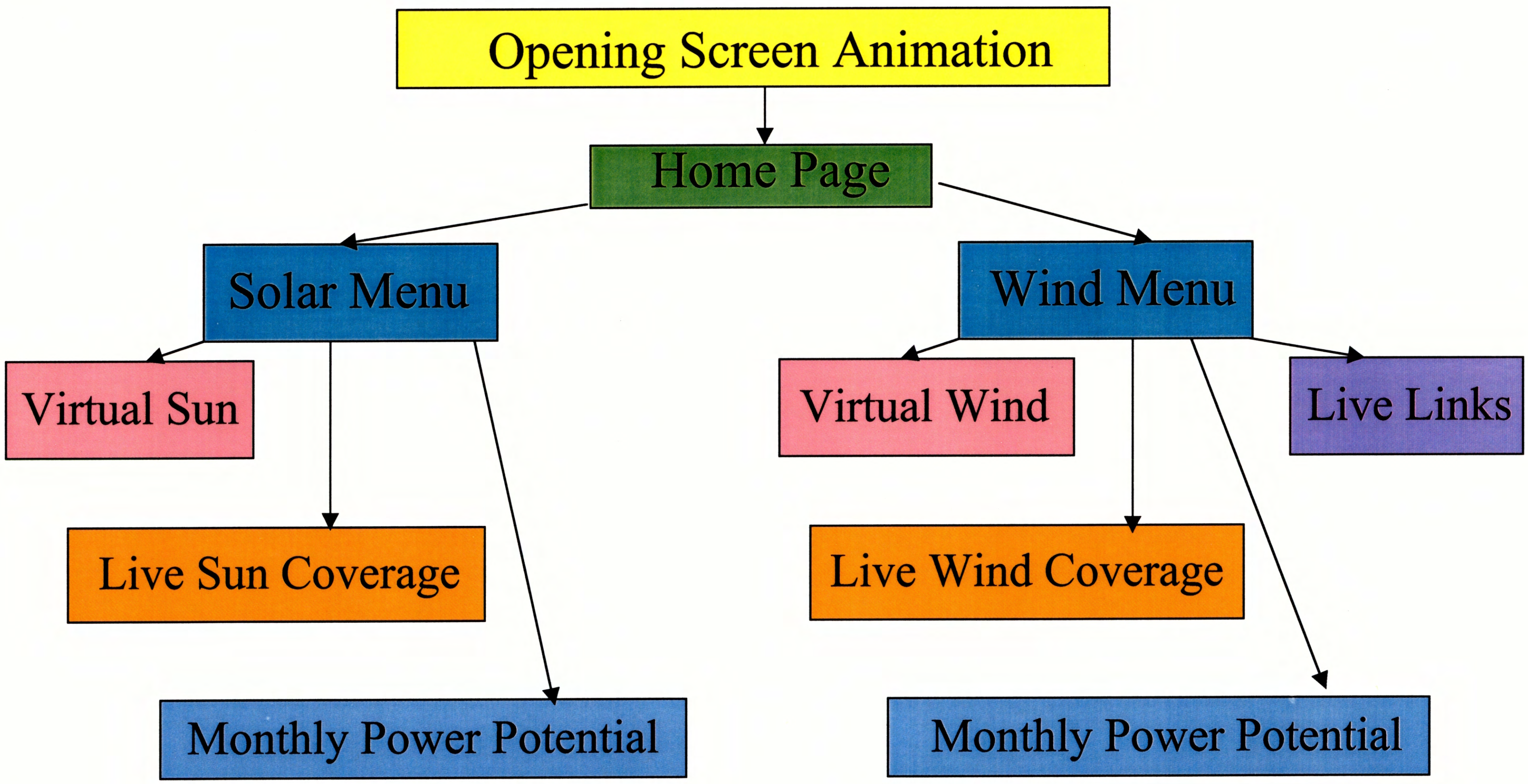
The program first connects to the web page, searches the document for the appropriate information, retrieves the information and finally places it in text files which the Flash exhibit can access and use. After completion, the program was thoroughly tested for accuracy of information and stability on the Museum network.

```
/*
   This program gets the current wind speed and weather in London
from cnn.com and dumps it to the file speed.txt and weather.txt.
Site.txt is a temporary file used.  Note: coding could be tighter but
all I/O is properly cleaned up.
*/

import java.awt.*;
import java.applet.Applet;
import java.awt.event.*;
import java.io.*;
import java.net.*;

public class GetSpeed extends Applet {

int n = 10;

public static void main(String[] args){
    String[] sites =
{"http://www.cnn.com/WEATHER/eu/England/LondonEGLL.html"};
    InputStream in = null;
    OutputStream out = null;
    char speed = 'x';
    char speed2 = 'x';
    char weather = 'x';
    int j=0;
    int i=0;
    int test=0;

    try {
      // Check the arguments
      if ((sites.length != 1) && (sites.length != 2))
        throw new IllegalArgumentException("Wrong number of
arguments");

      // Set up the streams
      URL url = new URL(sites[0]);    // Create the URL
```

```
      in = url.openStream();        // Open a stream to it
      out = new FileOutputStream("site.txt");

      // Now copy bytes from the URL to the output stream
      byte[] buffer = new byte[4096];
      int bytes_read;
      while((bytes_read = in.read(buffer)) != -1){
        out.write(buffer, 0, bytes_read);
      }
      out.close();

      File f = new File("site.txt"); // Create a file object
      FileReader cnn = new FileReader(f);            // Create a char
stream to read  it
      int size = (int) f.length();       // Check file size
      char[] data = new char[size];      // Allocate an array big
enough for it
      int chars_read = 0;                // How many chars read so
far?
      while(chars_read < size)           // Loop until we've read it
all
        chars_read += cnn.read(data, chars_read, size-chars_read);

      //search for string 'kph', the speed is 13 characters back.
      for(i = 0; i < size; i++){
      if(data[i] == 'k'){
          if(data[i+1] == 'p'){
            if(data[i+2] == 'h')

            if(data[i-14] != ' '){
                speed = data[i-14];
                speed2 = data[i-13];
              }
              else
                speed = data[i-13];
         }
        }
      }

      //search for 'sunny'.. if not found, the weather is cloudy
      i=0;
      //while(data[i] != 'k' && data[i+1] != 'p' && data[i+2] !=
'h'){
      while(i<size - 5 && test==0){
        if(data[i] == 'c' && data[i+1] == 'l' && data[i+2] == 'o' &&
data[i+3] == 'u' && data[i+4] == 'd' && data[i+5] == 'y'){
          weather = 'c';
          test = 1;
        }
      if(data[i] == 'r' && data[i+1] == 'a' && data[i+2] == 'i' &&
data[i+3] == 'n'){
        weather = 'c';
          test = 1;
        }
        if(data[i] == 's' && data[i+1] == 'n' && data[i+2] == 'o' &&
data[i+3] == 'w'){
        weather = 'c';
          test = 1;
        }
```

```
        if(data[i] == 's' && data[i+1] == 'u' && data[i+2] == 'n' &&
data[i+3] == 'n' && data[i+4] == 'y'){
        weather = 's';
          test = 1;
        }
        i++;

      }

      //write speed to 'speed.txt' if speed was successfully found
      if(speed != 'x'){
      PrintStream out1 =
        new PrintStream(
          new BufferedOutputStream(
            new FileOutputStream("speed.txt")));
      out1.println("livespeed=" + speed + speed2);
      out1.close();
      }

      if(weather != 'x'){
        PrintStream out1 =
        new PrintStream(
          new BufferedOutputStream(
            new FileOutputStream("weather.txt")));
      if(weather == 'c')
        out1.println("weather=cloudy");
      if(weather == 's')
        out1.println("weather=sunny");
      out1.close();
      }

    }
    // On exceptions, print error message and usage message.
    catch (Exception e) {
      System.err.println(e);
      System.err.println("Usage: java GetURL <URL> [<filename>]");
    }
    finally {  // Always close the streams, no matter what.
      try { in.close();  out.close(); } catch (Exception e) {}
    }
  }


}
```

Appendix I – Site Map



Appendix J – Web-Site Screenshots

Table of Screenshot Figures

Opening Page Before Revisions

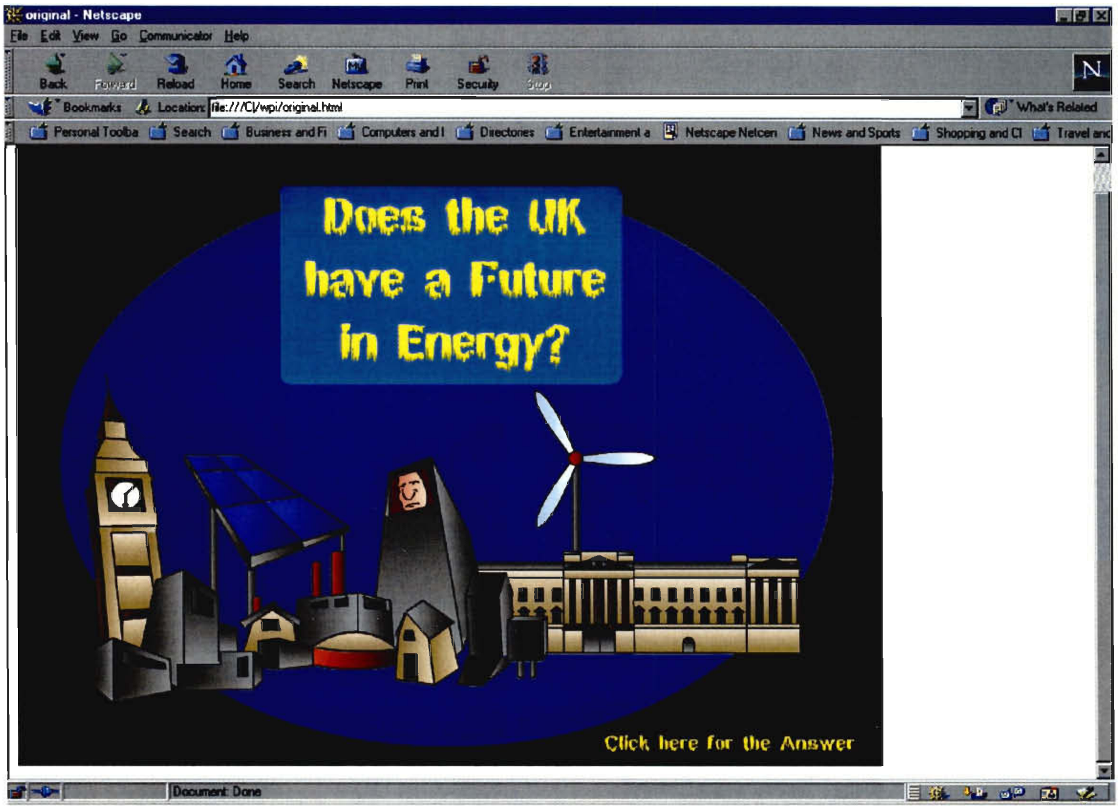


Figure J.1 - Opening Animation Page Before Revisions 1

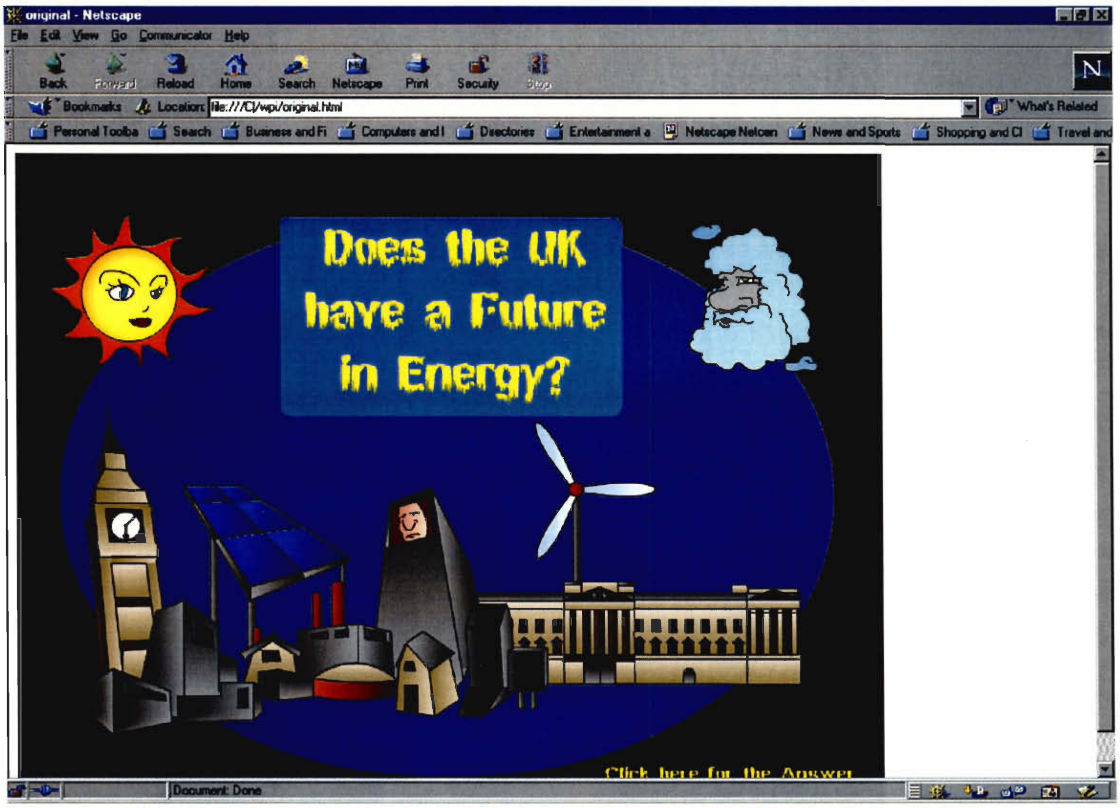


Figure J.2 - Opening Animation Page Before Revisions 2

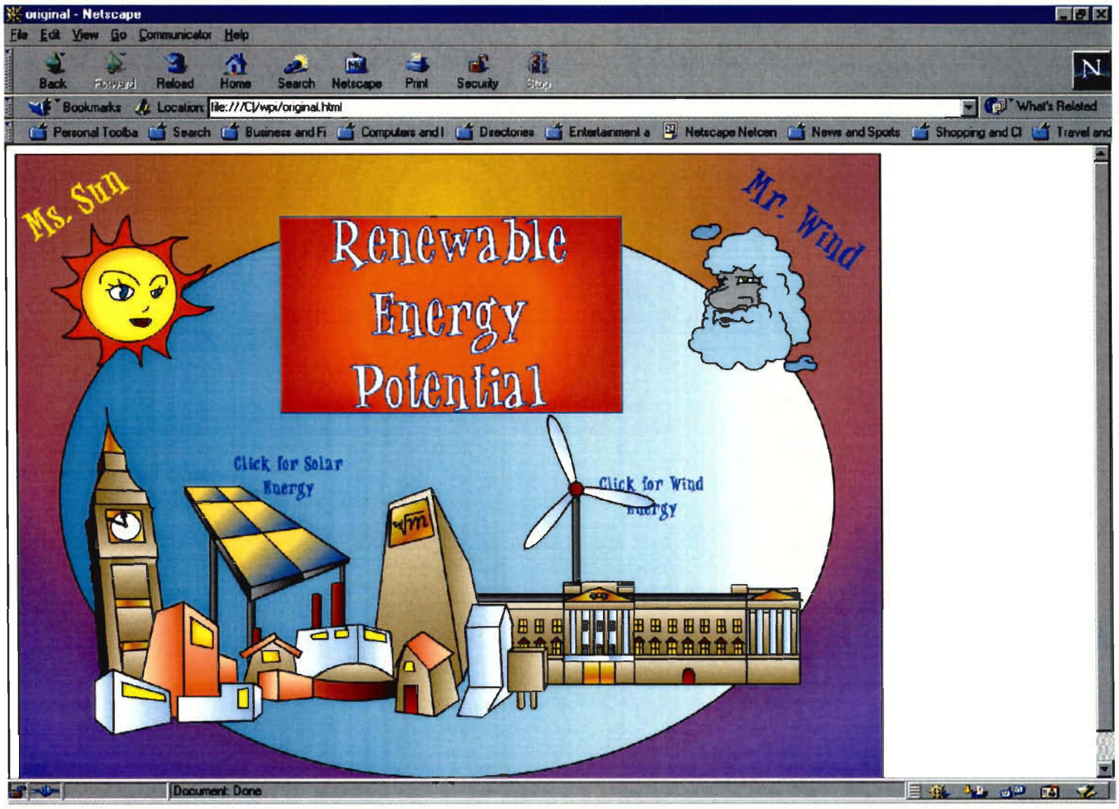


Figure J.3 - Opening Animation Page Before Revisions 3

Wind Section Before Revisions

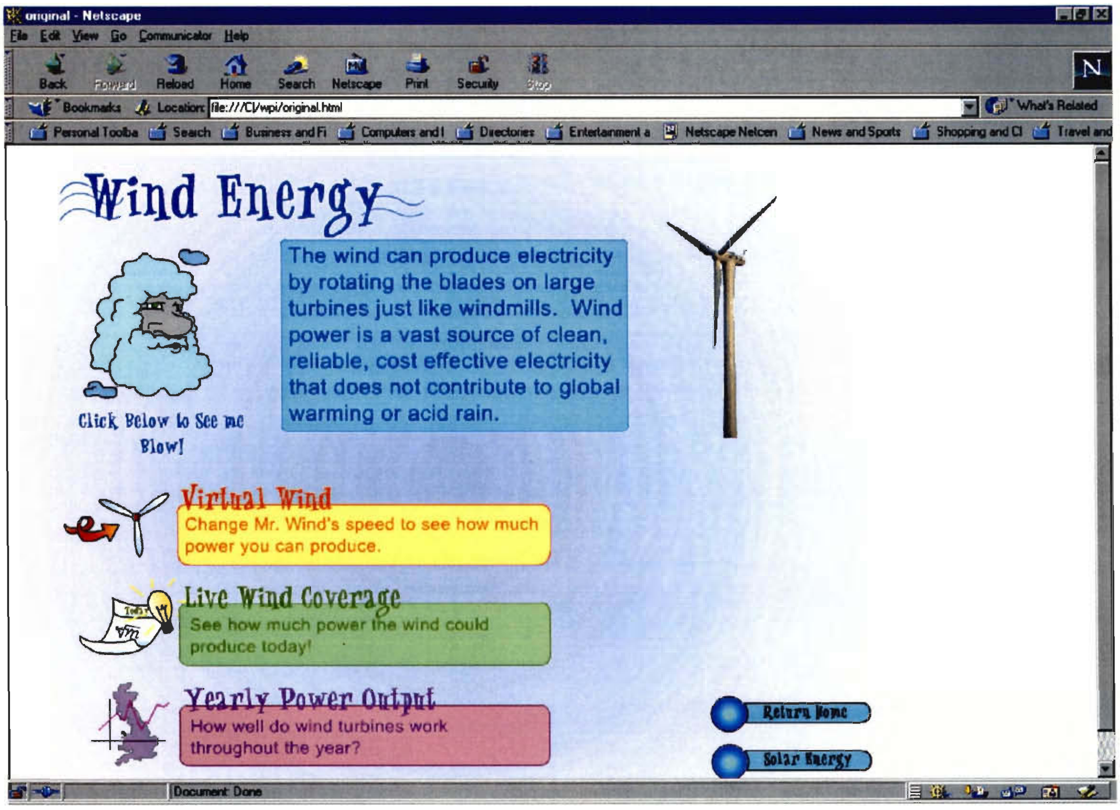


Figure J.4 - Wind Menu Before Revisions

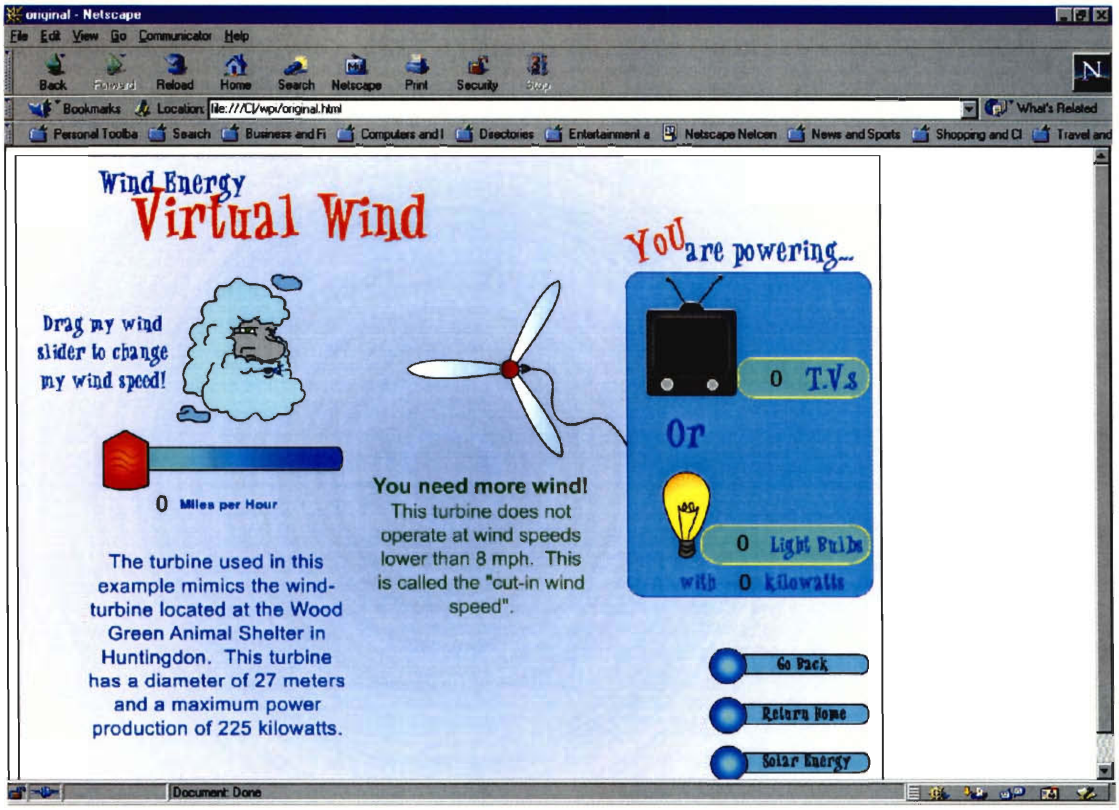


Figure J.5 - Virtual Wind Before Revisions 1

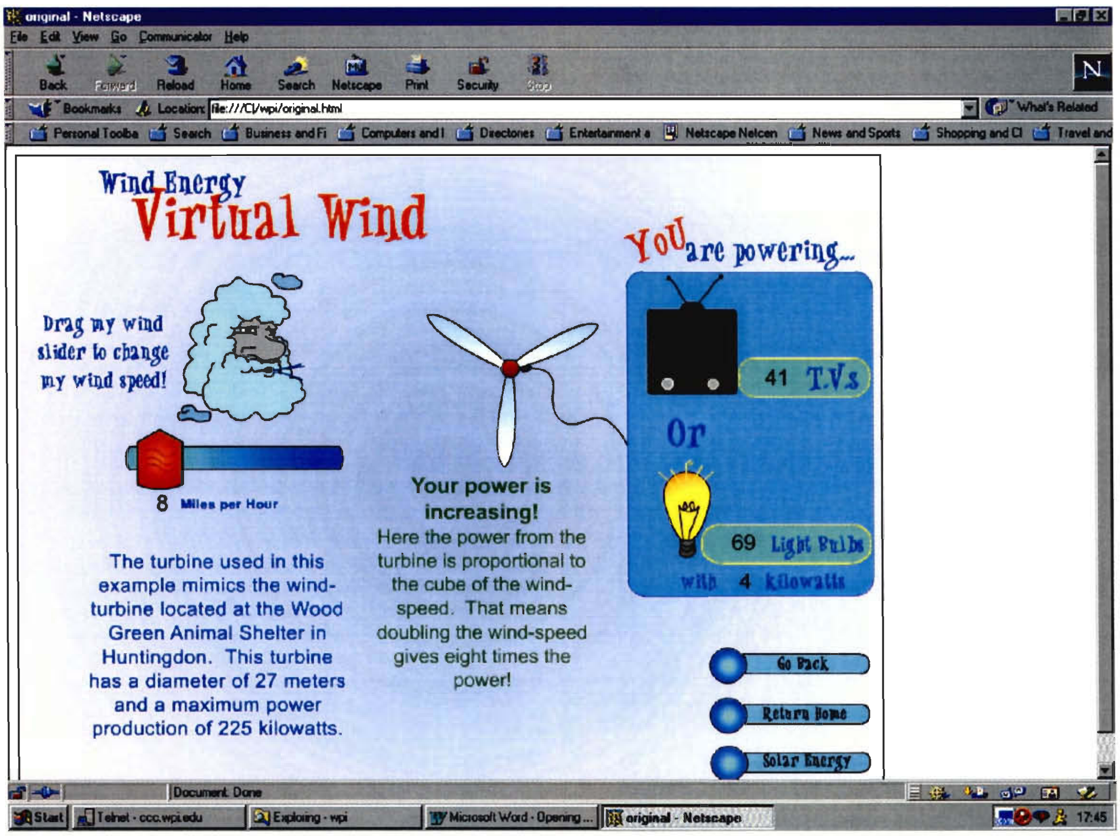


Figure J.6 - Virtual Wind Before Revisions 2

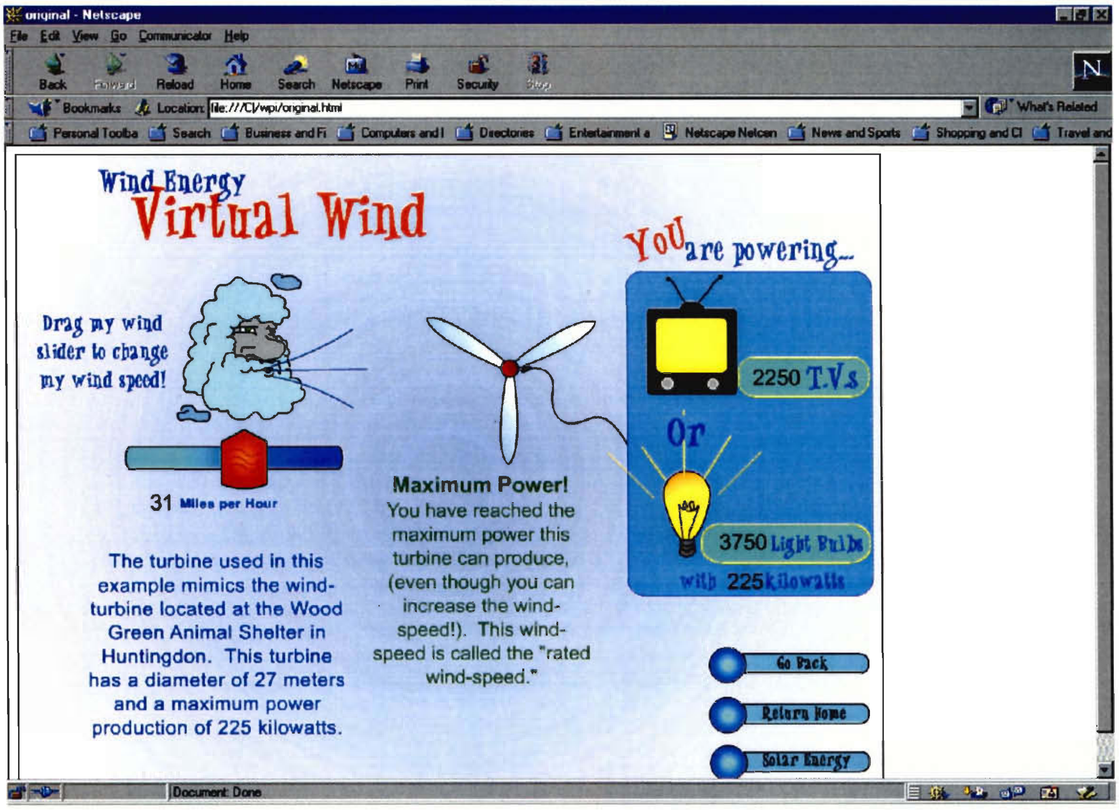


Figure J.7 - Virtual Wind Before Revisions 3

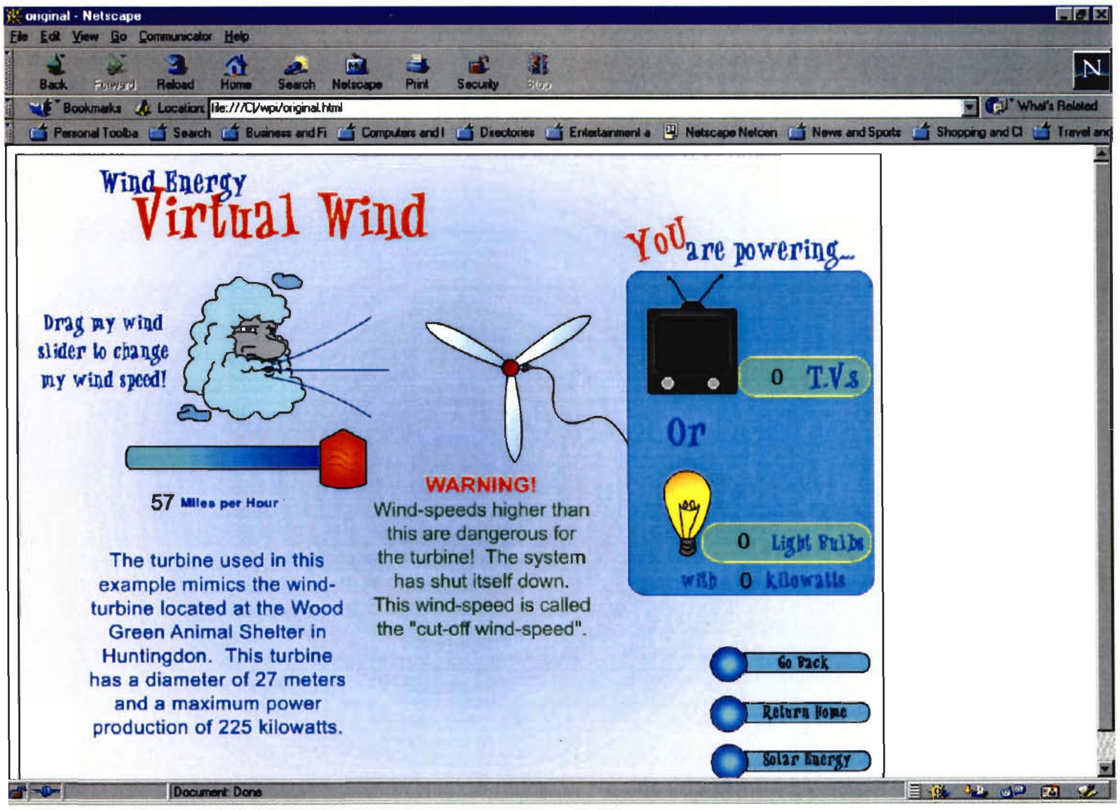


Figure J.8 - Virtual Wind Before Revisions 4

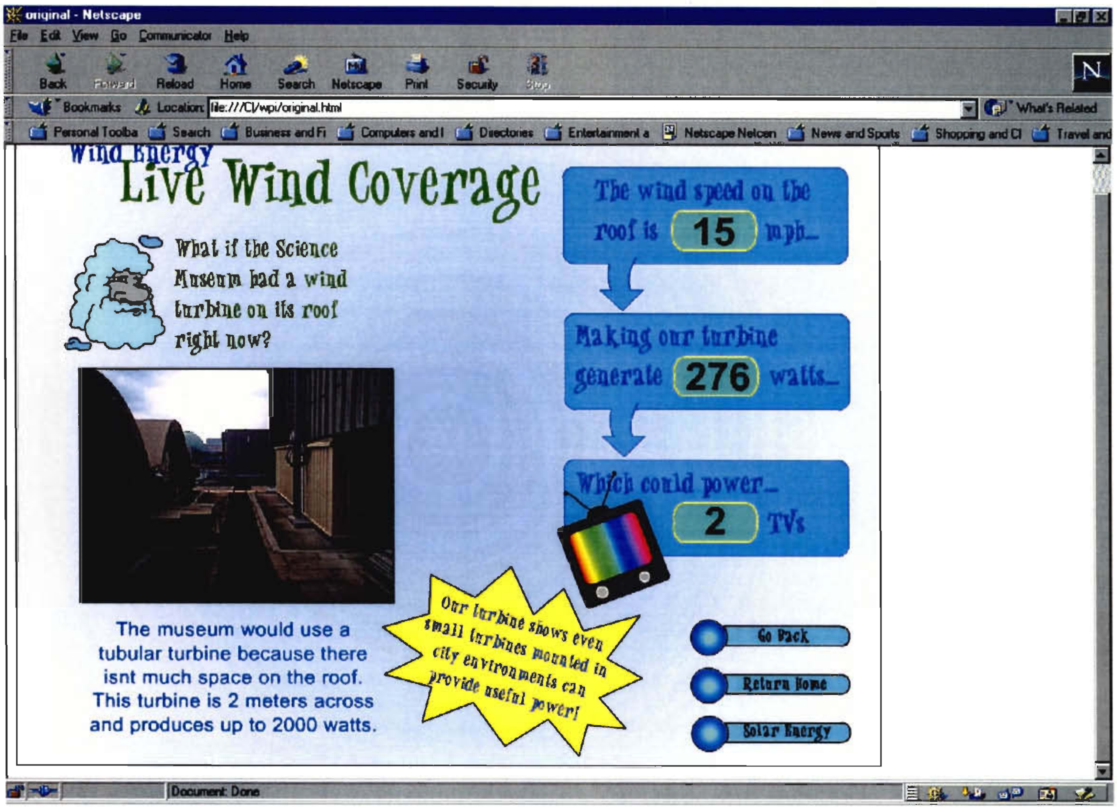


Figure J.9 - Live Wind Coverage Before Revisions

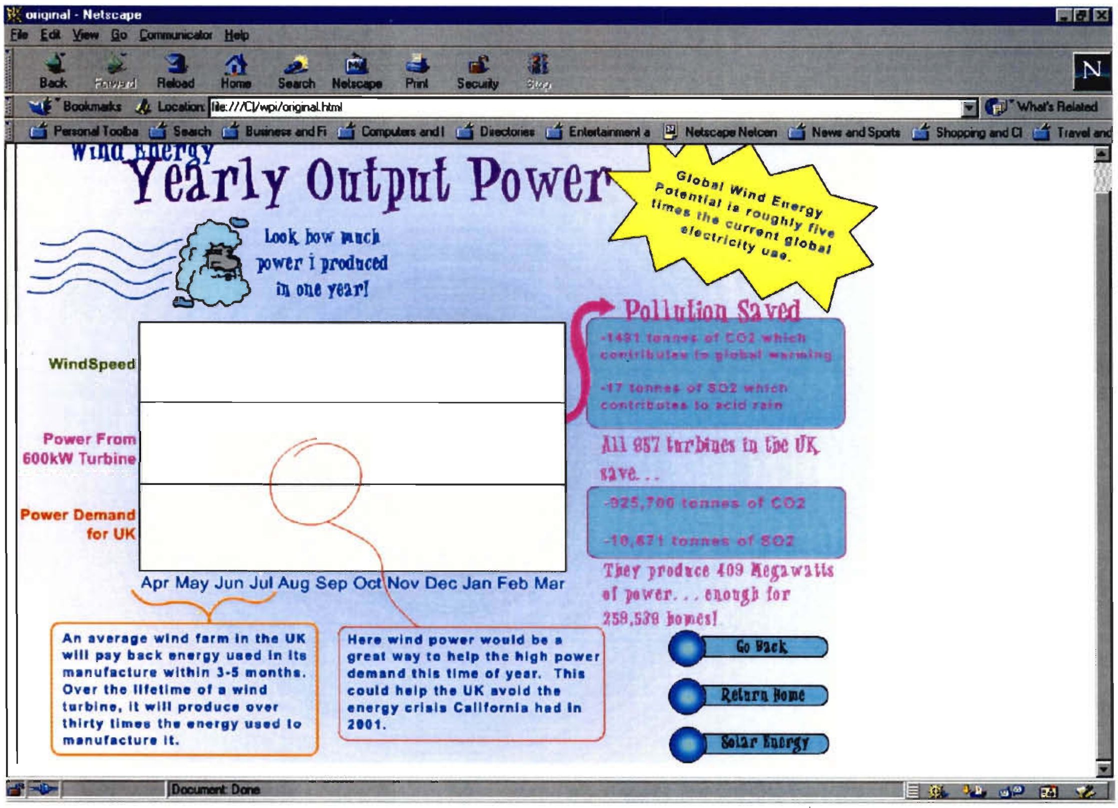


Figure J.10 - Yearly Output Power Before Revisions

Final Opening Page Animation

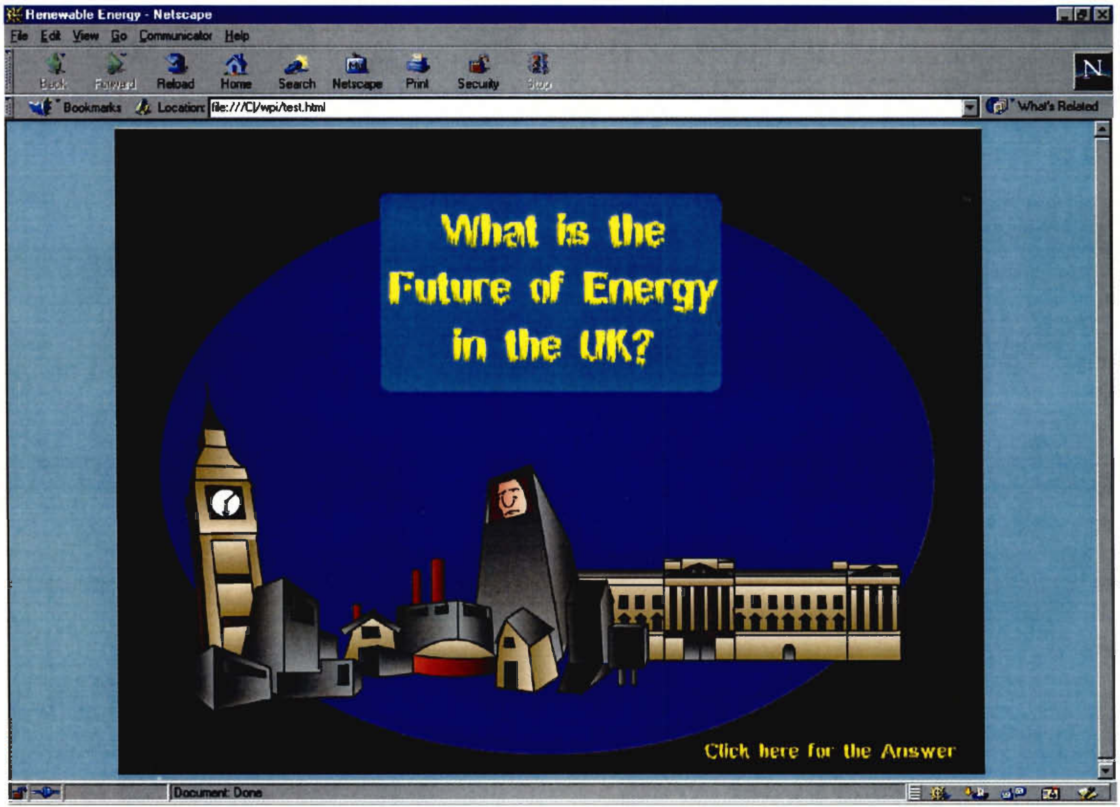


Figure J.11 - Final Opening Animation Page 1

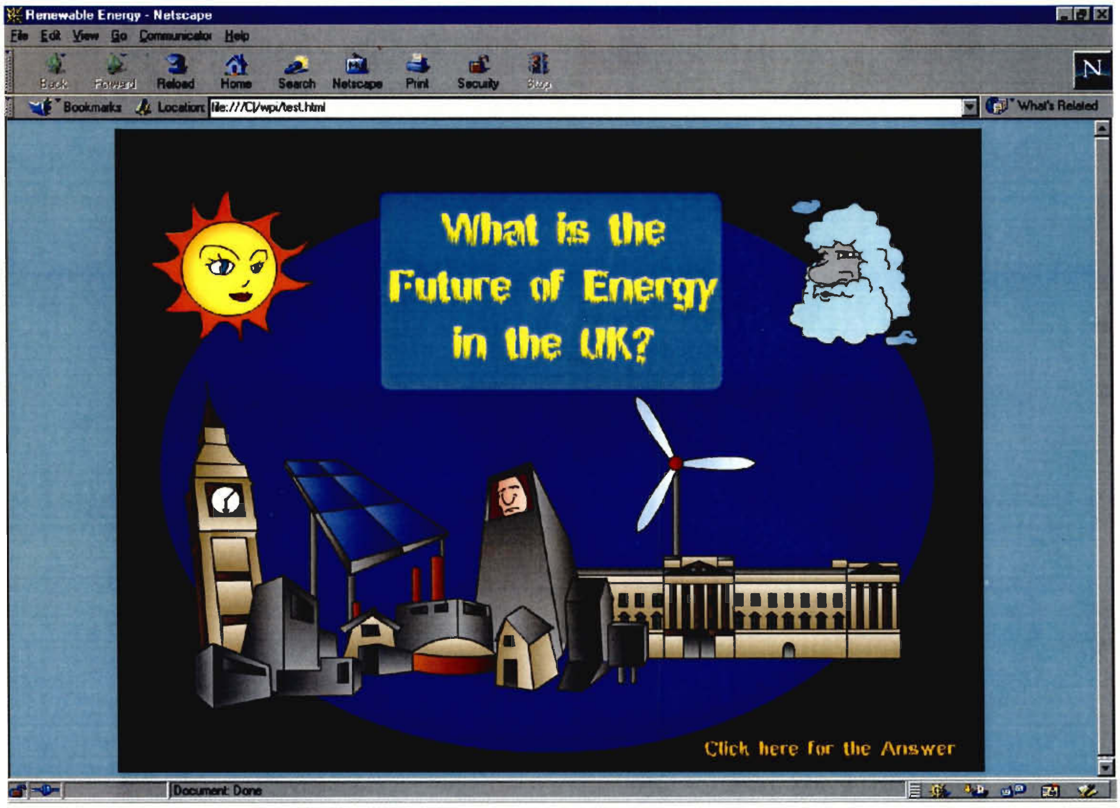


Figure J.12 - Final Opening Animation Page 2

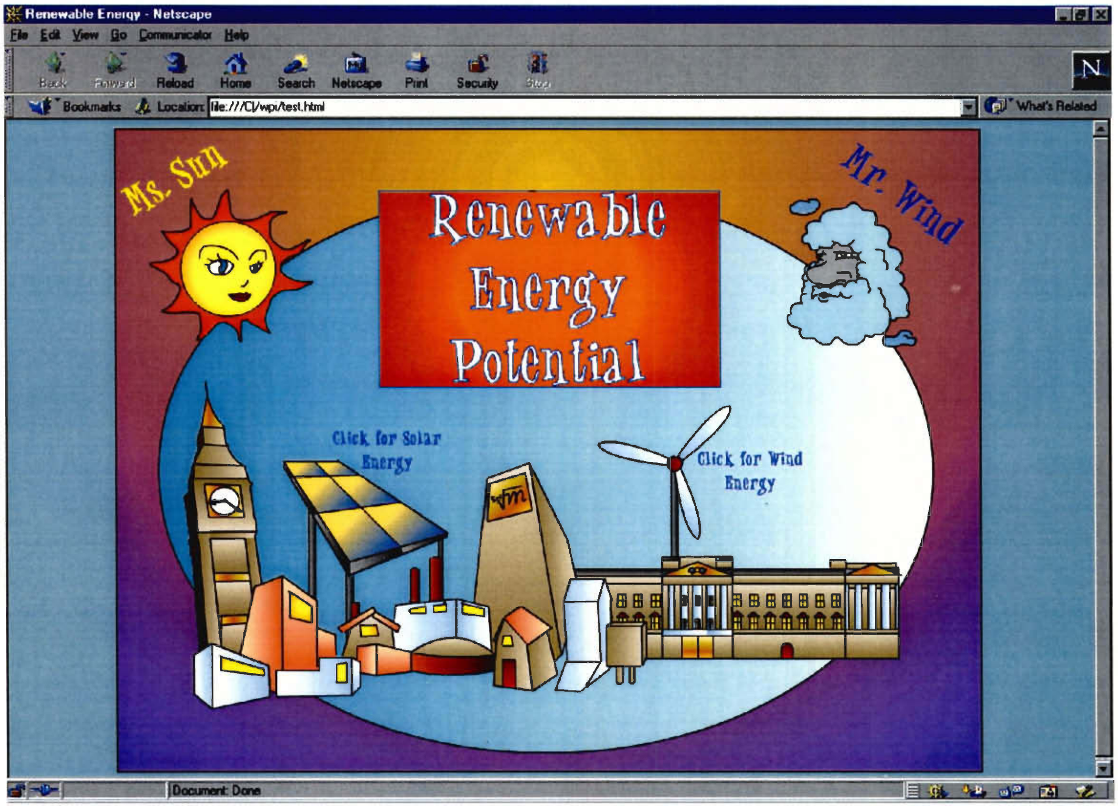


Figure J.13. - Final Opening Page 3

Final Wind Section

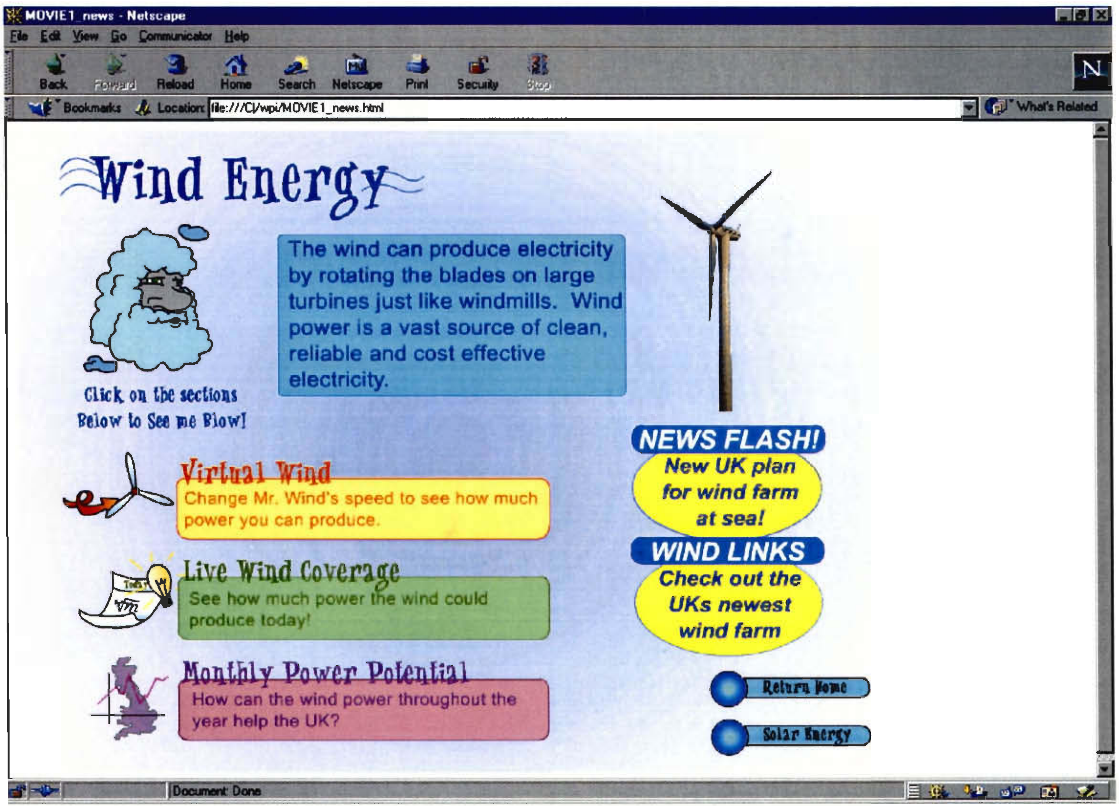


Figure J.14 - Wind Menu

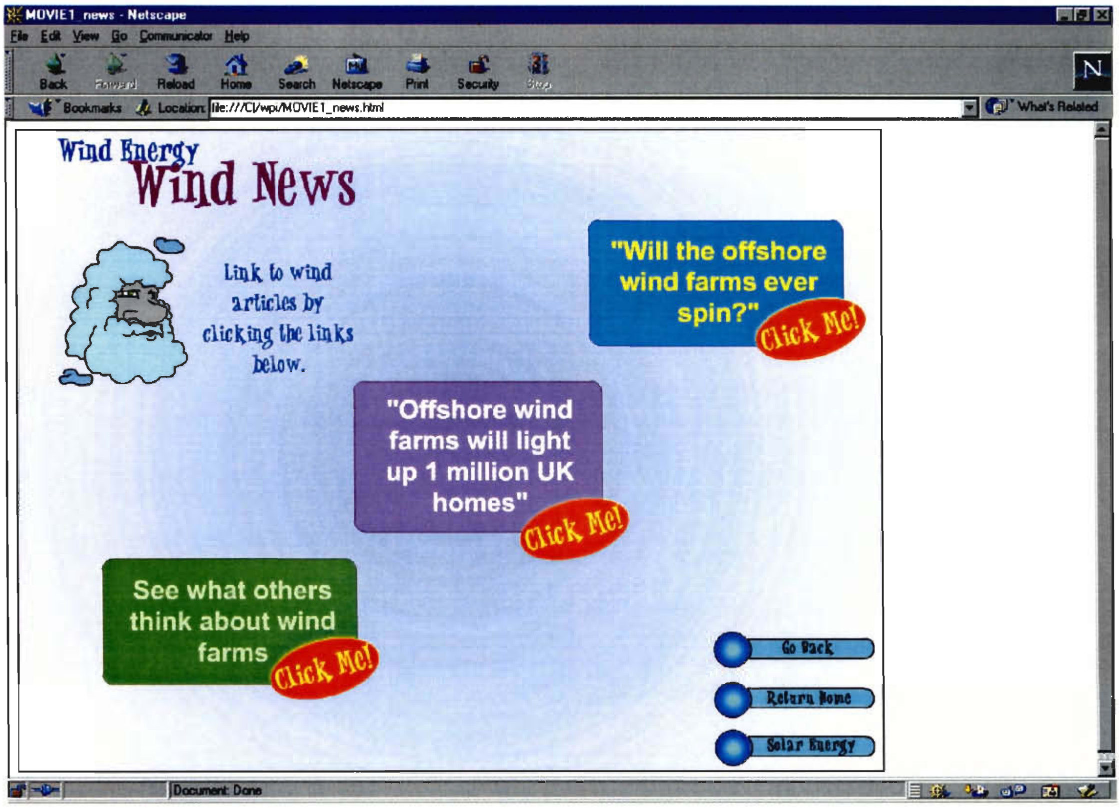


Figure J.15 - Final Links Page

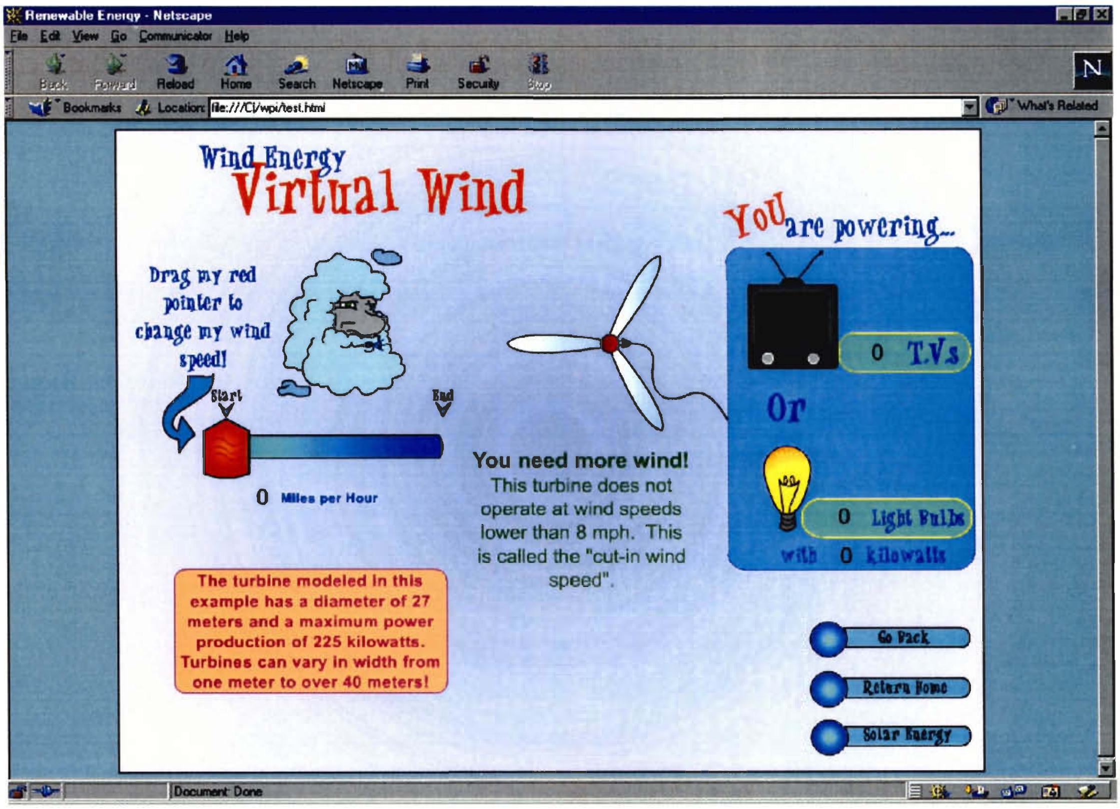


Figure J.16 - Final Virtual Wind 1

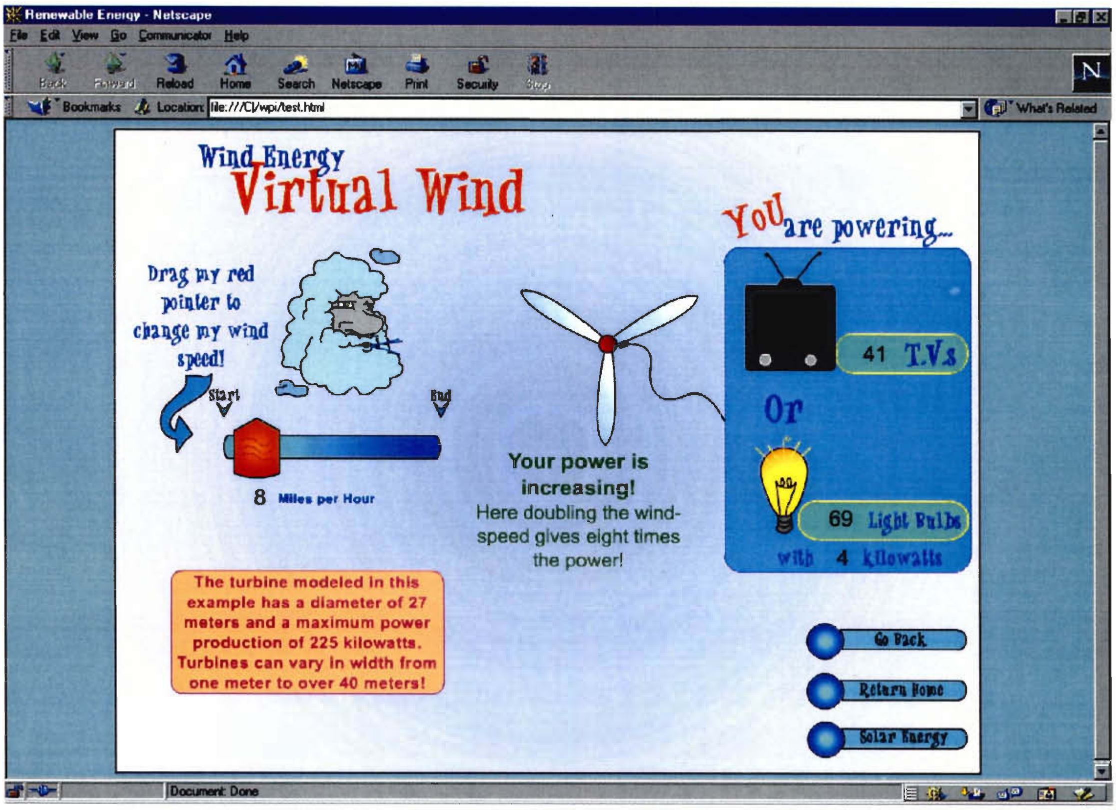


Figure J.17 - Final Virtual Wind 2

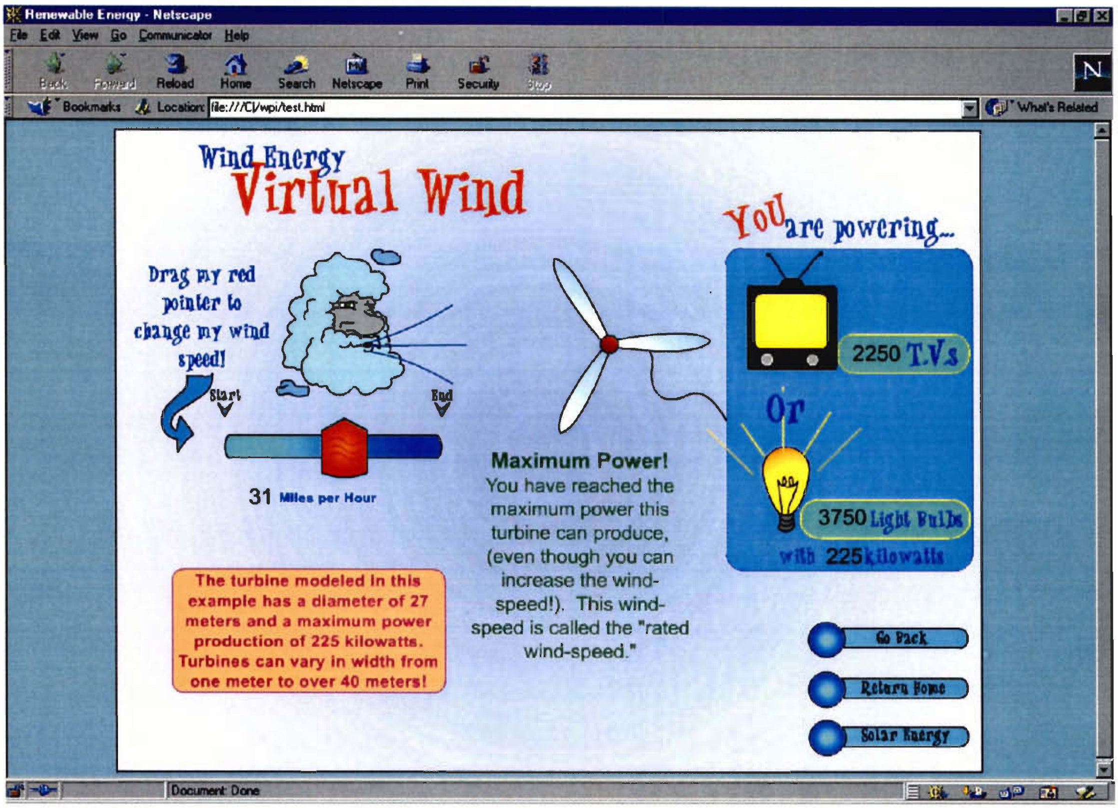


Figure J.18 - Final Virtual Wind 3

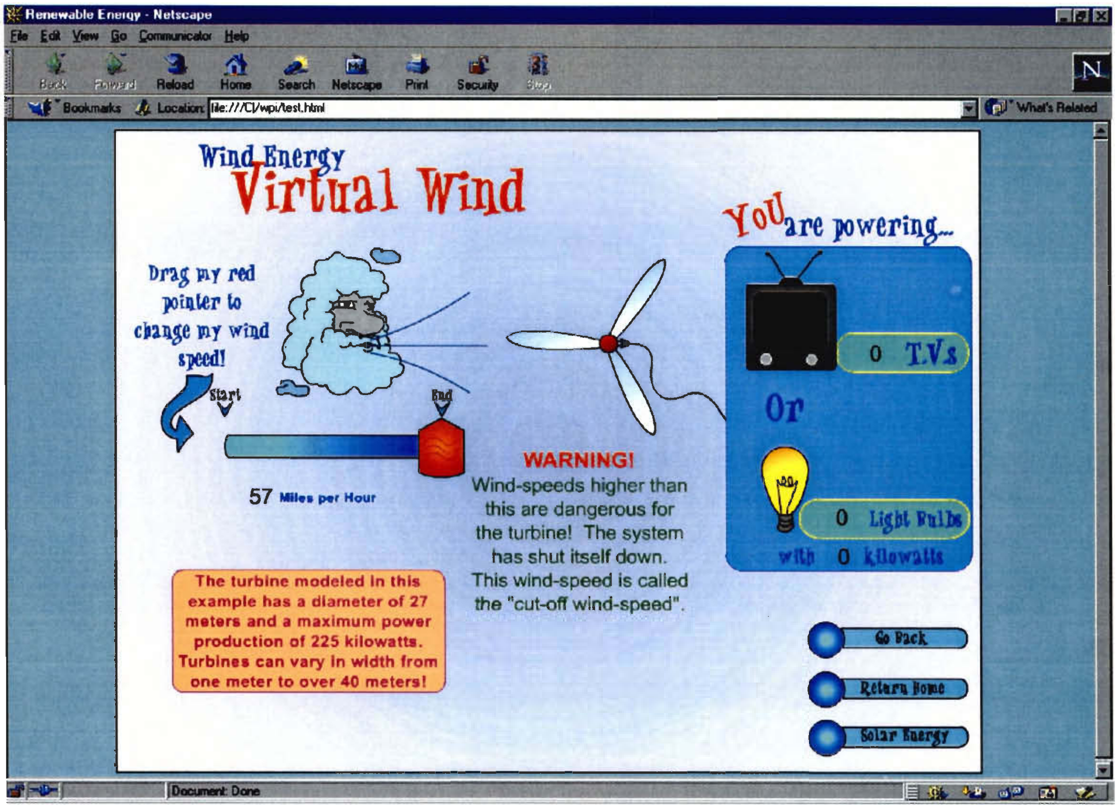


Figure J.19 - Final Virtual Wind 4

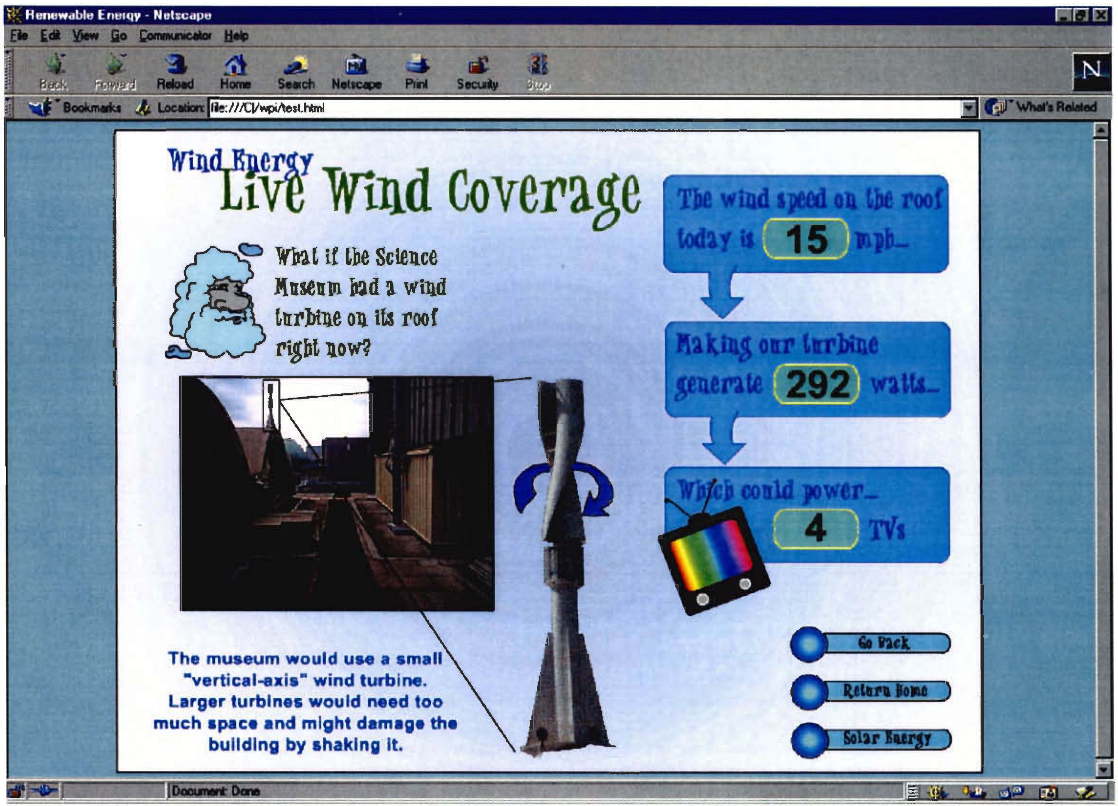


Figure J.20 - Final Live Wind Coverage Section

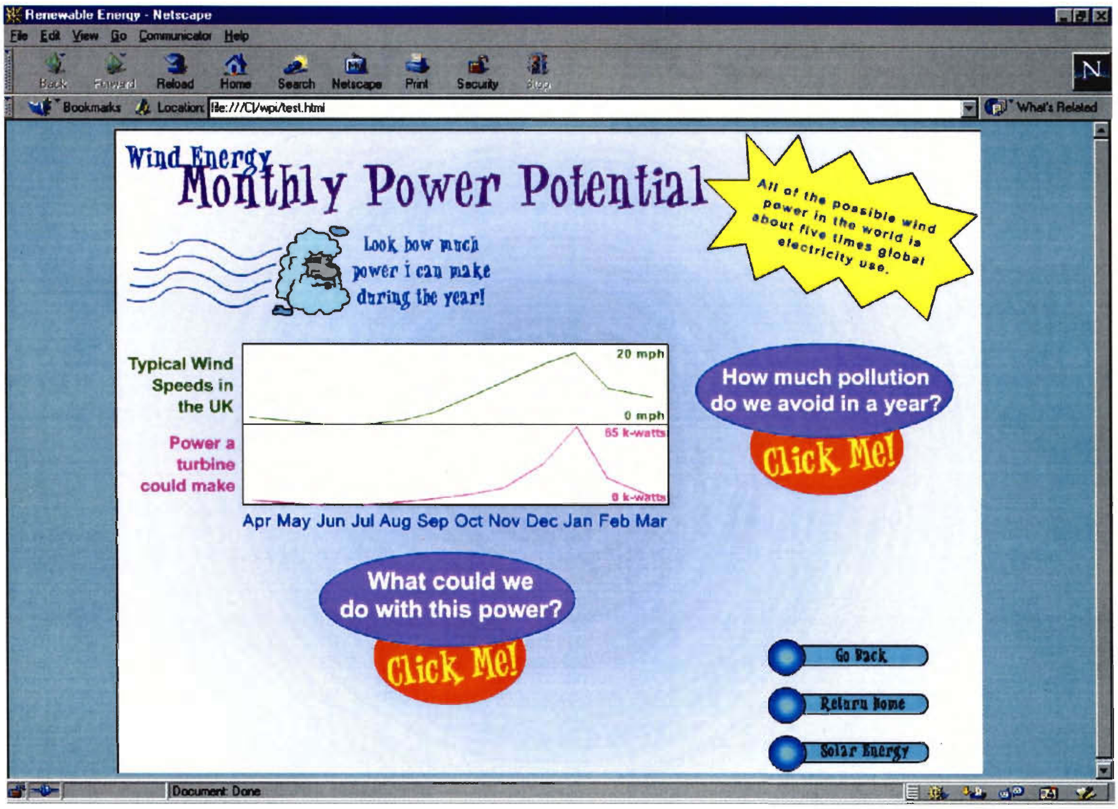


Figure J.21 - Final Monthly Power Potential

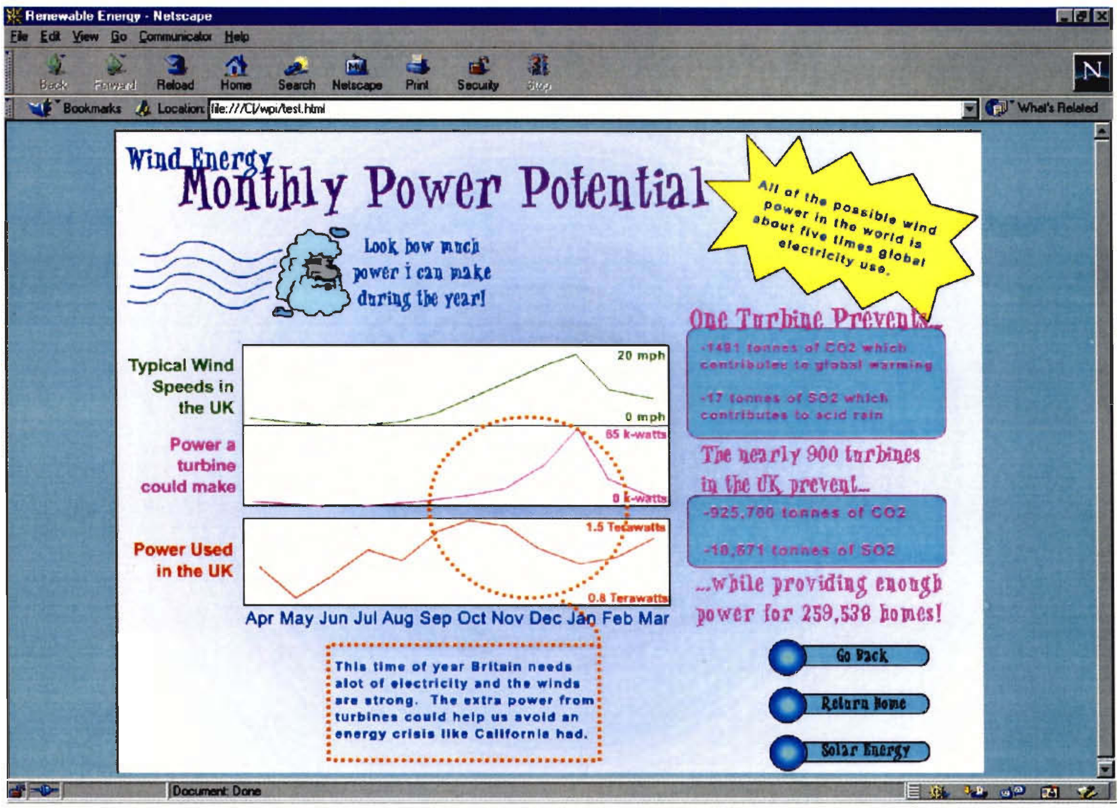


Figure J.22 - Final Monthly Power Potential

Final Solar Section

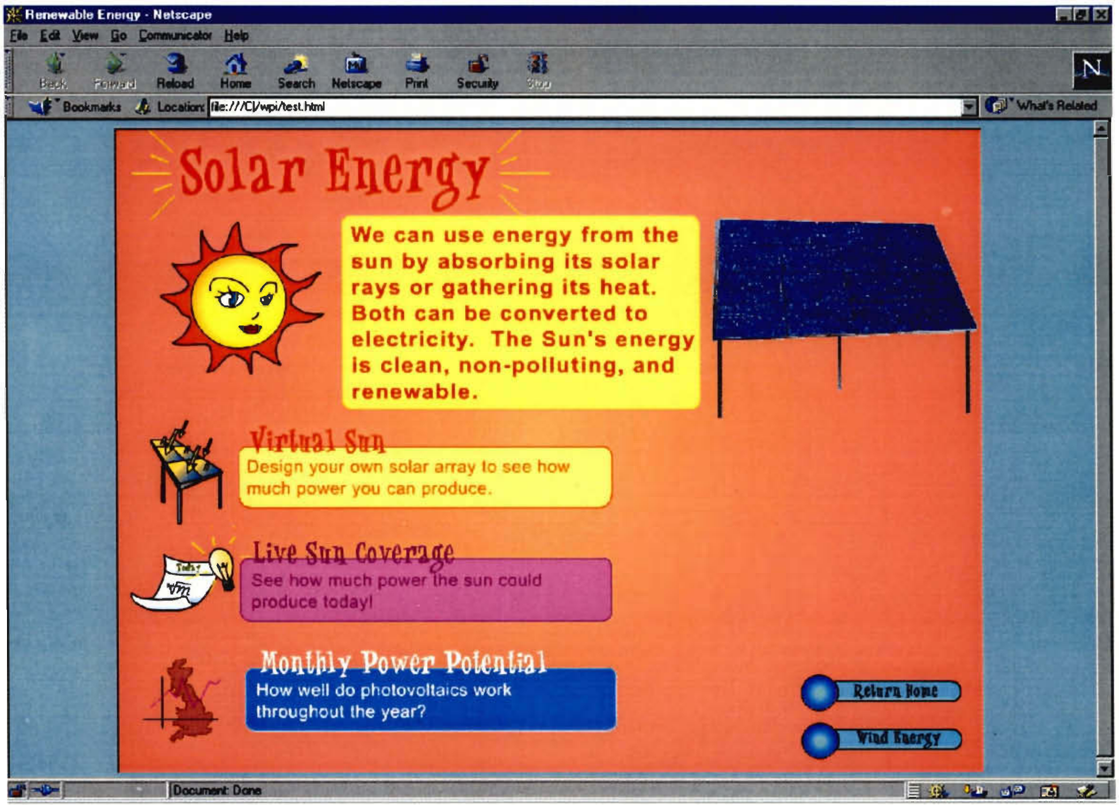


Figure J.23. - Final Solar Energy Menu

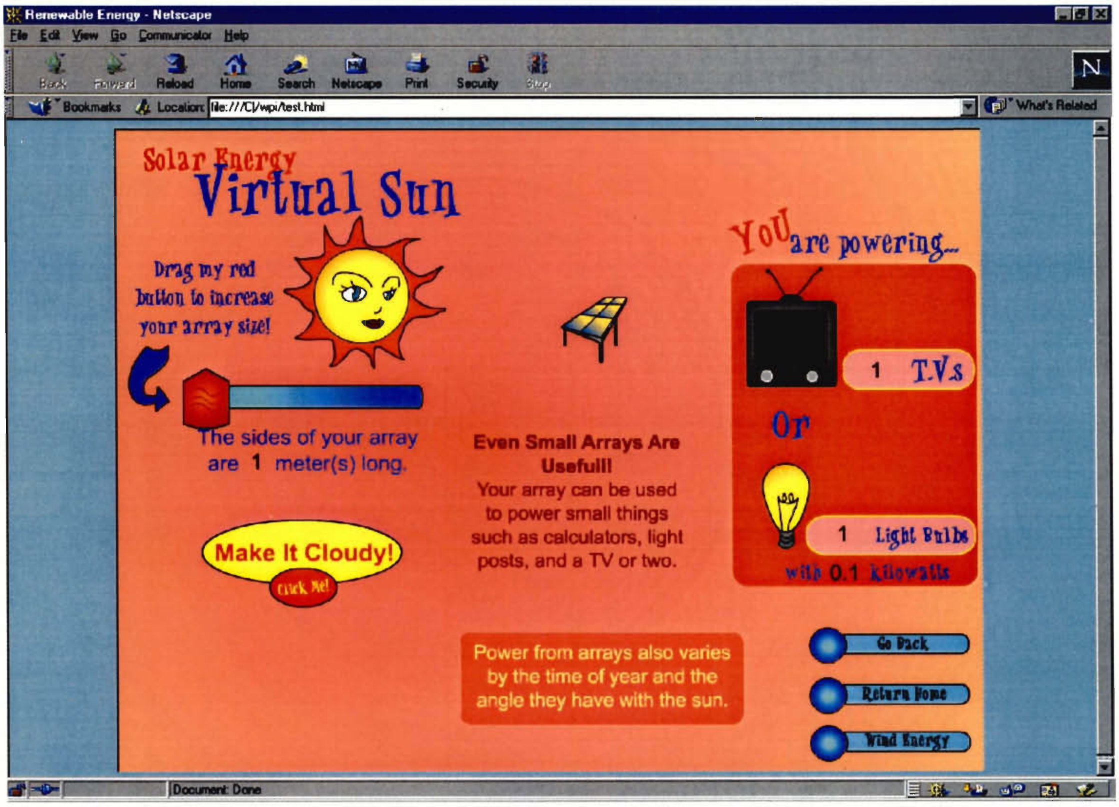


Figure J.24 - Final Virtual Sun 1

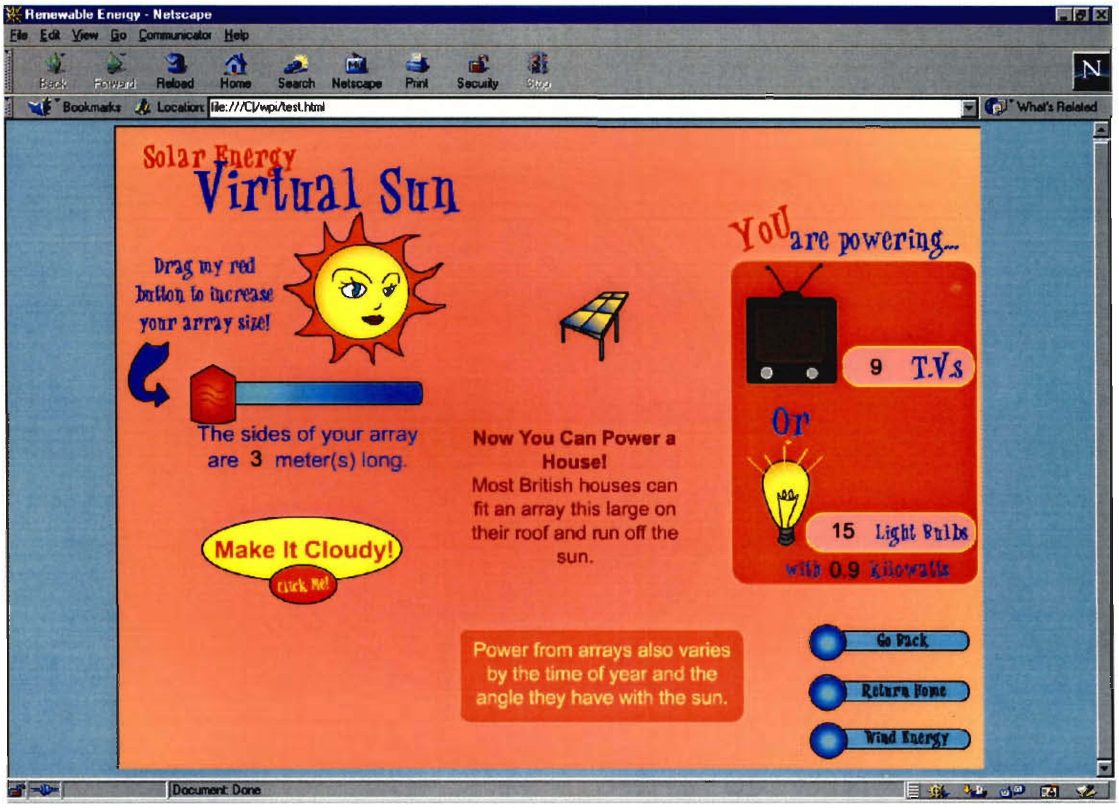


Figure J.25 - Final Virtual Sun 2

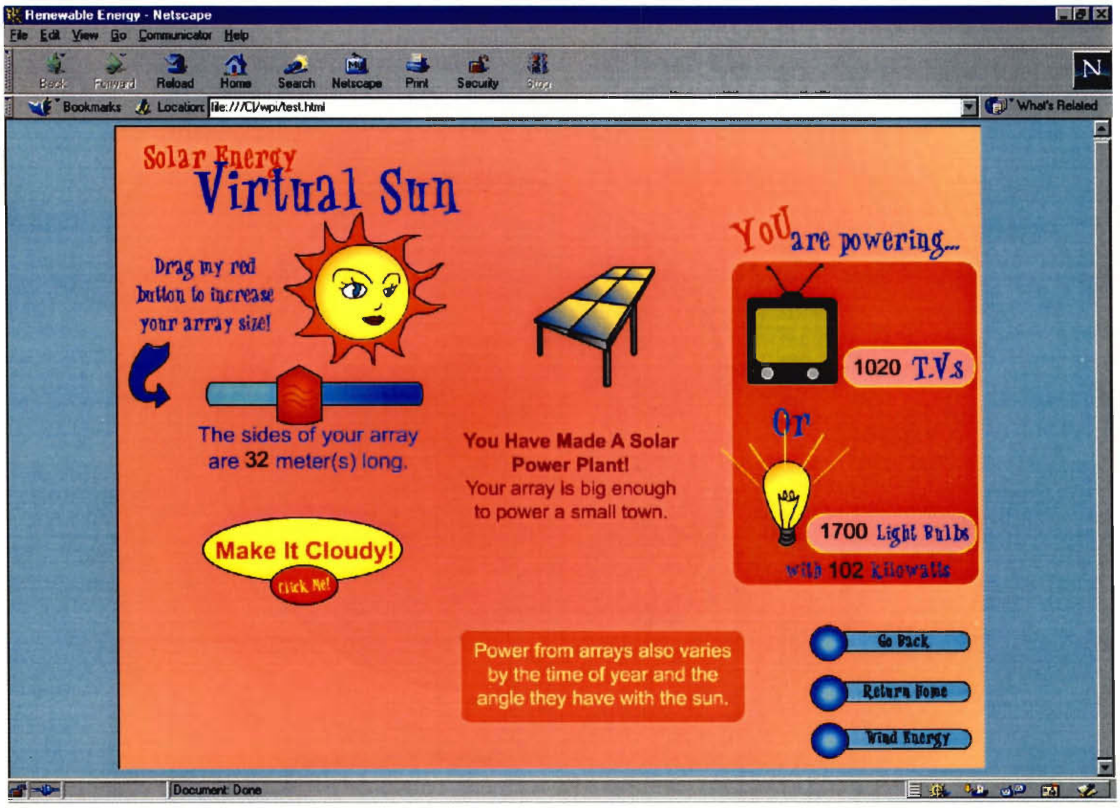


Figure J.26 - Final Virtual Sun 3

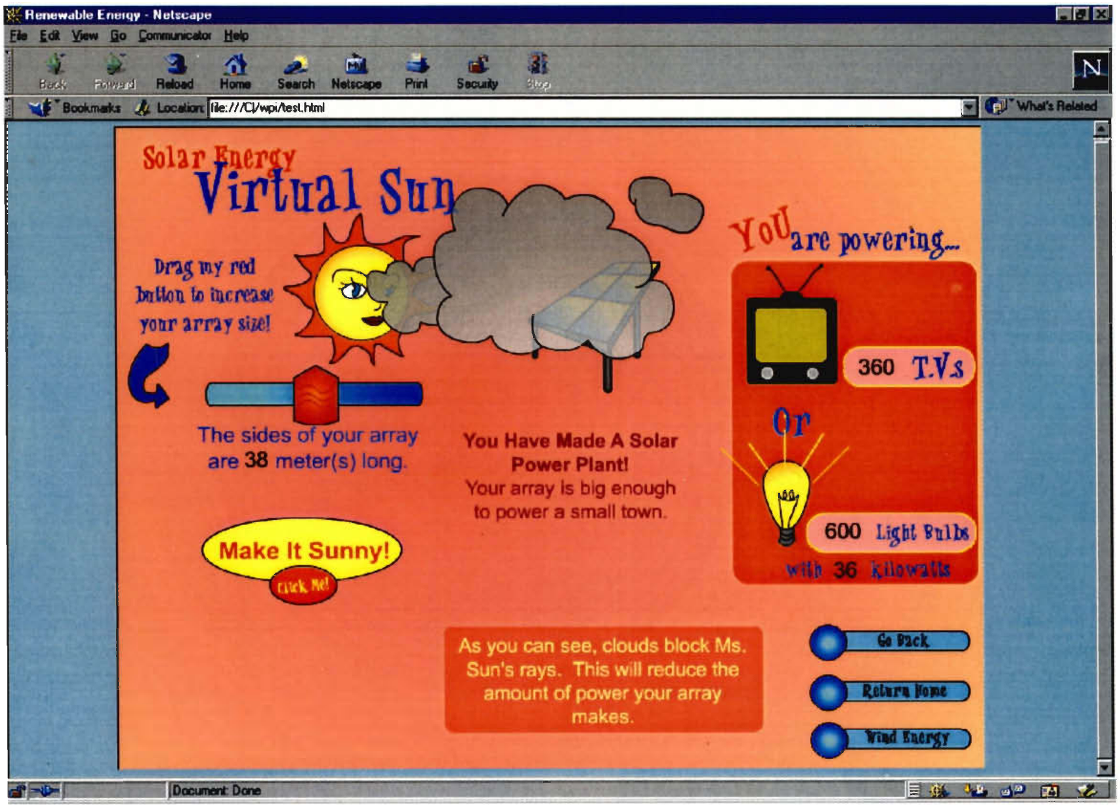


Figure J.27 - Final Virtual Sun With Clouds

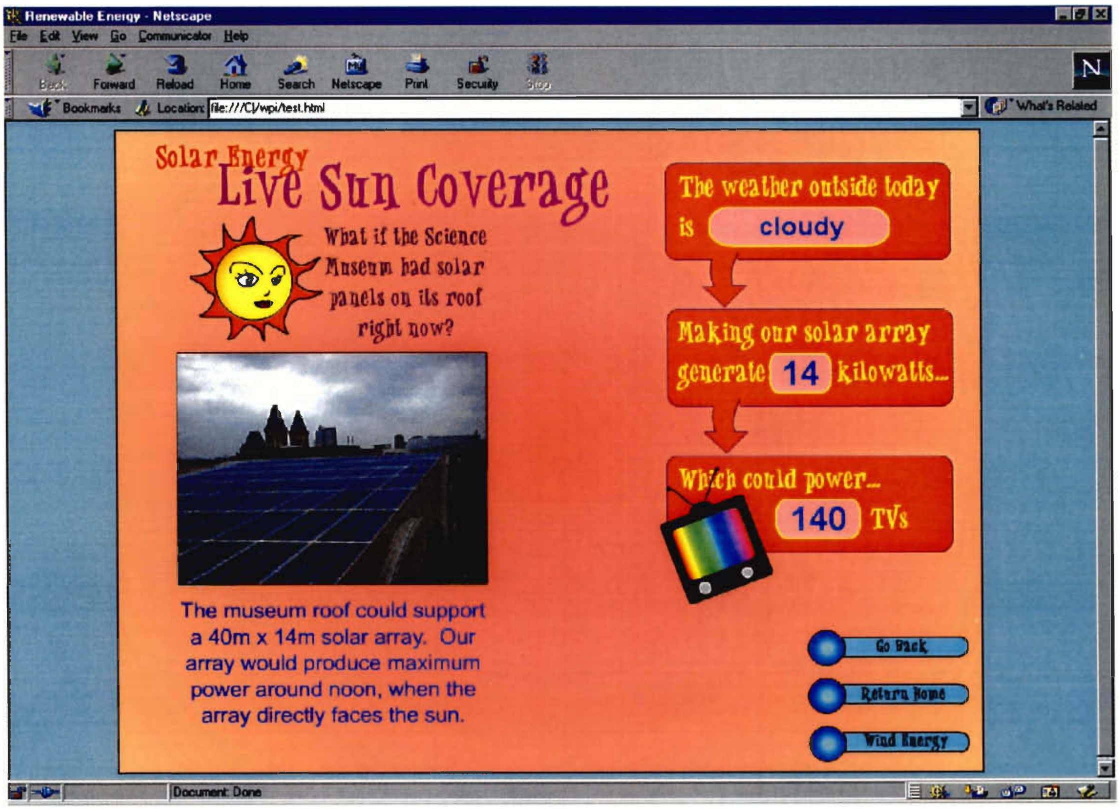


Figure J.28 - Final Live Sun Coverage

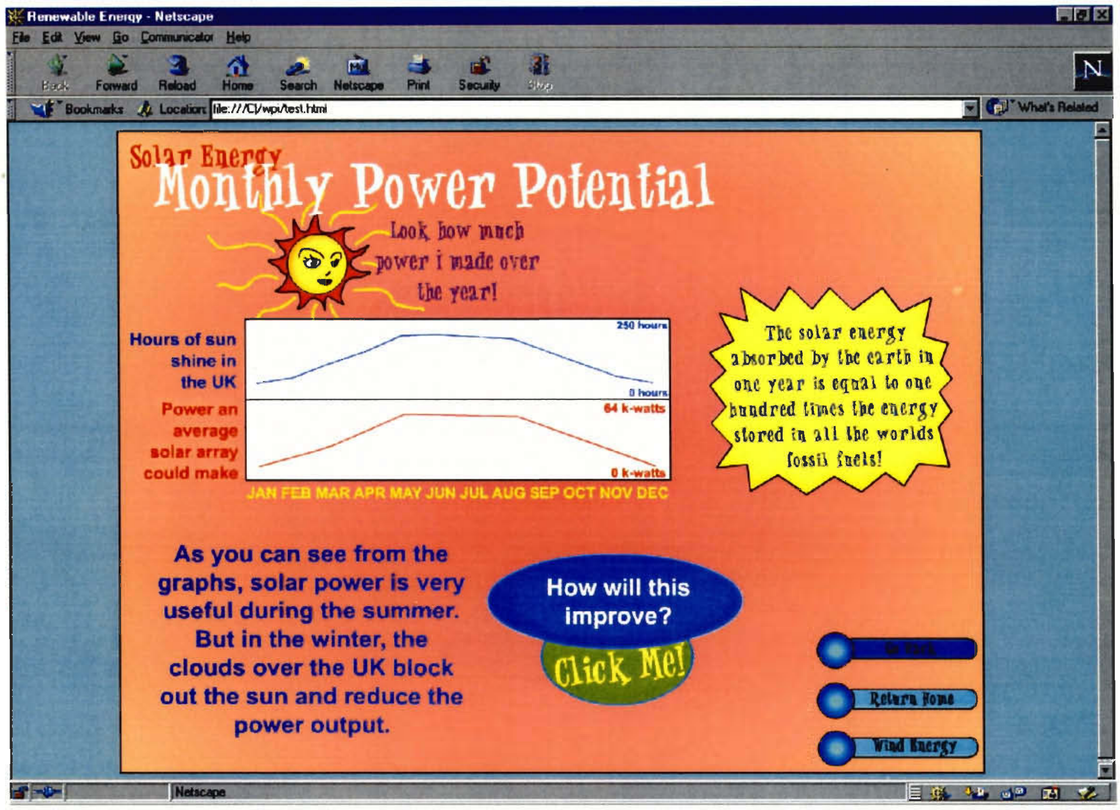


Figure J.29 - Final Monthly Power Potential: Solar 1

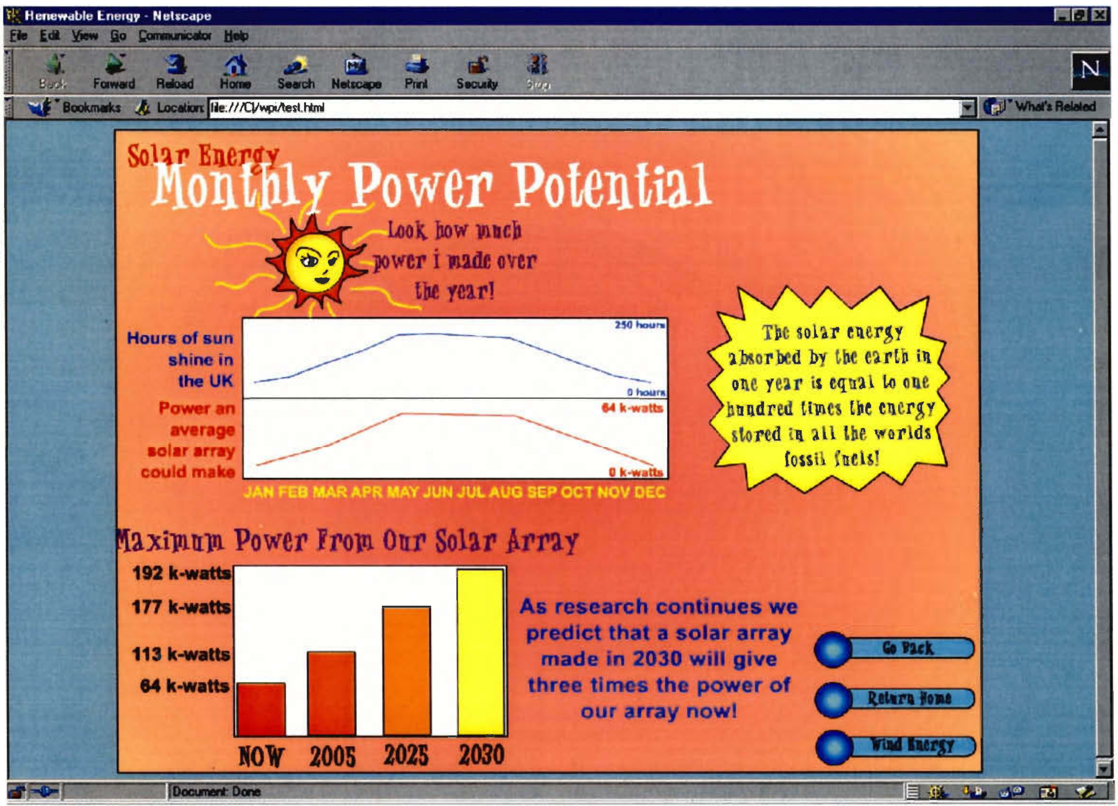


Figure J.30 - Final Monthly Power Potential: Solar 2