Project number: FN-GD01

DISTRIBUTED GREEN POWER TOOLS

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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Acknowledgements

Our group would like to thank everyone at the Massachusetts Technology Collaborative for their guidance. In particular we would like to thank Tyler Leeds for providing us with the decision tools and his input in our planning process. We would like to thank Professor Francis Noonan for being an excellent project adviser. Professor Noonan's knowledge and experience has helped us shape our general ideas into a cohesive plan of actions.

Table of Contents

Table of Figures

Table of Tables

Chapter One

Introduction

There exists a significant population of industrial firms who would be inclined to change from conventional utility-based energy supply, to a distributed generation option. Distributed generation is becoming a viable energy option for industrial firms as energy cost rise yearly. With an abundance of renewable energy sources industrial companies have more opportunities to develop energy on site. Distributed generation allows for a company to implement their energy alternative while still connected to the current energy supplier. Distributed generation is commonly achieved through net metering which allows a company to roll back the energy meter for energy produced onsite, which offers a substantial savings in energy cost by avoiding transmission costs from the current energy supplier. Generation of electricity through wind power systems, solar power systems, and or other renewable energy resources is often associated with environmental benefits; it also presents an economic incentive to industry over conventional energy resources.

Today there are many electronic applets in form of freeware programs in the form of Internet available programs, which allow industrial firms considering renewable energy options the ability to evaluate renewable energy options. The different types of analysis performed by such applets may include estimated project costs, annually savings, payback periods, and other financial figures. The freeware applets vary in their focus and capabilities, and can be divided into two main categories: Internet based programs, available in public domain and excel-based programs, which use a wealth of information stored in the form of, excel based macros. Scoring models as well as economic data in the form of cost benefit analyses will be generated for each of the decision applets. The purpose of this project will be to compare a number (probably four) of such applets, analyze them in terms of their usefulness to the industrial firm, and make a recommendation as to which applets best provide a firm with the information it needs to make a renewable energy decision.

Project methods and structure of the project

Now that we have defined the purpose of this study, let us discuss the procedures and methods, by means of which this project will be completed.

The first step would be to *become subject matter experts in the field of distributed generation and renewable energy*, as our evaluation applets are specific to these areas. In order to understand which applets are useful and which are not, we must have a very thorough understanding of the environment in which they are used. Given the limited time (as well as other resources) of the project, we do not expect ourselves to become an authority with regard to these topics; however, we believe it will be possible to become sufficiently familiar with them. In order to do that, we will devote more than a quarter of our research, to researching the topic of Renewable Energy and Distributed Generation. Research will rely on primary sources, such as the actual government regulation documents and possibly current research in that field, and secondary sources, such as books, magazine articles and Internet sources. Under the topic of Renewable Energy there will be three major research subgroups: identification of non-renewable energy types, assessment of current renewable energy resources and a focused study of specific portable renewable energy type such as solar thermal and wind power systems. Under the topic of Distributed Generation there will be two major subgroups: definition of the distributed generation, with its history and applications and research of the electric utilities, mainly concerned with the government policies and regulations, including such important moments as licensing, quotas and protocols. **This research will be placed in the 2nd and 3rd chapters of the project report.**

Upon completion of the research on distributed power and renewable energy we will move on to the *study and research of the actual applets to evaluate a renewable energy initiative*. We have decided that we will focus on freeware applets, as these are readily available via public Internet sites. We will further divide these freeware applets into two types, Internet based and excel based applets and get at least two different applets of each type. We will take time to study and describe each of the applets in detail. We will also conduct a study on the feasibility of the use of those applets, since running them requires a specific set of data, some of which may not be available. In this case we will act as if we were the manufacturing company. We will take a certain applet, see what data it takes to run and then try to gather this data by means of primary and secondary research (not unlike the research in the very beginning of the project). We will take note on how easy or how hard it was to gather the data, and whether some of the data is available at all or not. It is a common knowledge that a more thorough analysis always requires more data, so there is always a tradeoff between the quality and speed of analysis. Doing the assessment of data availability will allow us to see which applets are more quality oriented and which are more speed oriented. **This study will be placed in the 4th chapter of the project report.**

At this point we consider that all the necessary research is done, and we are ready to move to the actual evaluation of the applets. The first step in this process will be to *develop the evaluation criteria*. We have already discussed the quality and speed of analysis, but additional criteria might be user friendliness, compatibility with the operation system of the user, availability on the market and other important technical or non-technical aspects. We will start off with a brainstorm, and then, after coming up with as many possible criteria as possible, we will sort them out, deciding on which criteria are valid and which are not. A thorough justification will be provided for each criterion. **This will be placed in the 5th chapter of the report.**

Now that we have the applets description and are sufficiently familiar with them and also have the criteria, according to which the applets have to be evaluated, we will do the actual evaluation of the applets. The evaluation will be both qualitative and quantitative. Such evaluation techniques as the scoring models will be utilized. It is possible that Internet based applets will be evaluated separately from excel based applets; however, applets will be evaluated against each other. Although we are not looking to decide on which applet is absolutely the best, we want to know which applet is the best to use in a given situation. For example, an evaluation for a large-scale manufacturer with a big budget will not be the same for a small manufacturer. Again the availability of certain data will play a big role, because in some cases certain applets will not be feasible to use at all. **This evaluation will also be placed in the 5th chapter of the project report.**

At this point in the project we assume that the bulk of the work is done, so the next important thing is to bring it all together, to put a cap on it all. Here, we will write a conclusion to the project, which briefly reminds the reader of the strength and weaknesses of each applet and give our final suggestions. We will also write about some future considerations, discussing additional work that could have been done, if we had more time to spend on the project and an access to more of the decision tools. **The conclusion and future consideration will be placed in 6th chapter of the report.**

Chapter Two

Distributed Generation Background

Basics

Distributed Generation (DG) is defined as “power generation technologies that can be sited at or near the load they serve”[1]. It is an alternative to Centralized Generation, which uses large-scale power generating technologies located at one particular spot, and distributes power to the loads via long-distance power lines. In contrast DG utilizes small-scale utilities – compact and portable. Although traditionally, wind-, solar- and hydro-powered systems are not considered to be a part of the distributed generation concept, because of their dependency on the availability of respective natural recourses,. In this project, the decision tools we are evaluating deal with the “green” power alternatives and because their technology has improved and utilities have become a lot more versatile, “green” power alternatives are a viable alternative within DG.

In the history of energy industries, a similar development pattern is detectable. Power started out as distributed, went from distributed to centralized, and today it is coming back to distributed once again. For example, gas supply systems, started out as distributed power, with many smaller extraction sites, which then delivered gas to customers through shorter-distance pipes. However, by 1870, all major European cities had centralized their gasifiers and created a complicated distribution system. This was done to take advantage of the economies of scale, meaning that the marginal cost of one unit of gas would be smaller that way. Electricity industry went through a similar trend. It started out as a collection of smaller generating stations, which supplied only to a limited

[1]Anne-Marie Borbely and Jan F. Kreider, Distributed generation : the power paradigm for the new millennium, Boca Raton : CRC Press, 2001, p.2

area, and such stations were not connected with each other, until 1920. The reasons for centralization this time were not only the economical factors, but also the technical aspects and the drive for better reliability, since connected stations can share the loads and therefore get through the power demand peaks, with their partners providing a "back-up" in cases of failure. Eventually, fewer bigger ones replaced many small stations.[2]

Today, society has to adjust to the fact that our planet's finite resources are coming to an end. Resources are becoming scarcer, and new solutions are needed. In this respect, DG, with a lot of small generators, scattered effectively throughout the power grid can help save resources by lowering the costs of building and maintaining the distribution lines. In contrast to original reasoning, today, "green" power and distributed generation are linked very closely, since the renewable power sources are usually built in small, portable units.[3]

Economic factors in detail

Original arguments for the centralization of power supply were based on economies of scale. Due to the lowered costs of DG use, some people might believe that the economies of scale no longer exist in power generating. This is incorrect, because pure scientific reasons will always be on the side of larger generators. The most important factor here is that size improves thermal efficiency. If we take any given power generator and increase its size in all three dimensions, its volume will increase by a factor of eight, while its surface will increase by only a factor of four. This will mean an increase in overall productivity with a decrease in the heat loss to the surrounding

[2] Anne-Marie Borbely and Jan F. Kreider, Distributed generation : the power paradigm for the new millennium, Boca Raton : CRC Press, 2001, p.3
[3] Philipson, Lorrin, Understanding electric utilities and de-regulations, New York : M. Dekker, c1999, p. 119-146

medium, such as air. Even the generators that do not use heat as the primary means of generating power will benefit due to the a lesser loss of power due to friction.

However, this purely physical reasoning has one condition that has to be satisfied in order for it to be true. The larger generator will always be more efficient than the smaller one *given equivalent levels of technology*. However, since the creation of large-scale generators requires a lot of capital, and is subject to much many more regulations and restrictions from the side of the government, it is inevitable that the smaller generators are far ahead technology-wise. Smaller generators, available today, come from a newer age, while the bigger power plants can be from 20 to 50 years old. One might say that it is unfair to compare two classes of electricity generation across different vintage e, but in this project we are trying to look at the issue through the eyes of an industrial firm, and that will be the reality of their comparison.

Still, even comparing the generators of different sizes, on the same technological level, it is obvious that through the modern developments the advantage of large size has shrunk significantly. The reasons for that are[4]: pure technological innovation in the field of small power generators, due to the extensive R&D, improvement in materials, including metals, ceramics, carbon-fiber and others permit vastly stronger and less expensive *small* machines to be built, computerized control systems that dramatically reduce the number of malfunctioning and improvement in data-communication systems and off-site monitoring technologies which allow for better and more efficient maintenance.

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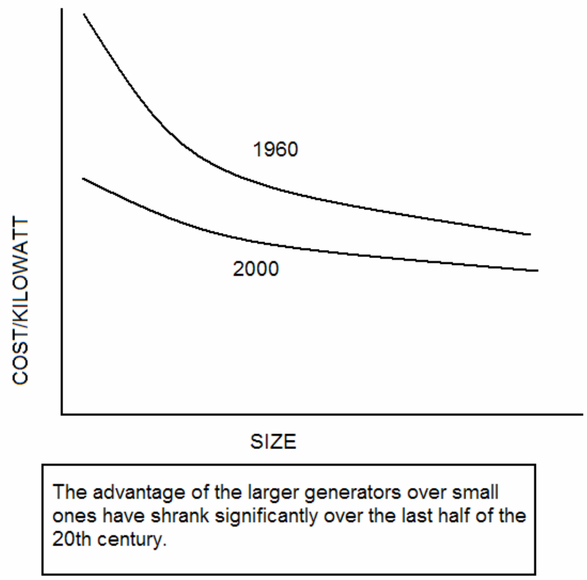
[4] Philipson, Lorrin, Understanding electric utilities and de-regulations, New York : M. Dekker, c1999, p. 136

All of those reasons have led to shrinkage in the advantage of bigger generators over smaller ones, going from as much as 60% in the middle 20th century, to about 30% in the end of it[5].

Figure # 1 – Generator size VS electricity cost



However, even if the cost advantage of large size has shrunk, the main reasons of DG's cost advantages lie in a different area, which is the various overheads that add on to the power costs, as it goes from the producer to the consumer, in our case the industrial company. DG units "win" over centralized power, because of their dramatic reduction, and virtual elimination of Transmission and Distribution costs (T&D). T&D costs are associated with the building and maintenance of the complicated networks of power distribution lines, which in practice can cost more than the power itself! The chart below displays the situation very well[6]:

[5] Figure #1:Walter G. Scott, Distributed Power Generation: Planning and evaluation, New York, M. Dekker, c2000, p2

Figure # 2 – Electricity costs breakdown

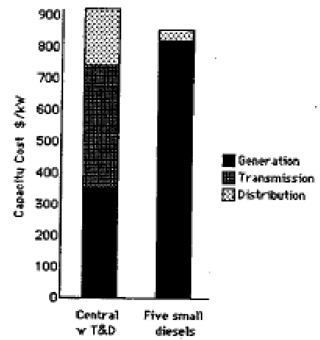


Figure 6.6 The capacity costs of traditional system expansion versus that of a set of small generators added at various points in a rural area. Distributed generation proved more efficient, not because the generation was more cost-effective, per se, but because local generation was more cost-effective than central station generation and the T&D system costs necessary to deliver the energy from the central station to rural customers.

It is also important to note that during the period of 1955-2000 the T&D costs have risen by about 35%, due to increased labor costs, and environmental, design and aesthetic restrictions put through by the government.[7] Today, despite the higher costs of actual power generation, the overall efficiency of DG is higher than that of centralized power usage. According to experts' claims, the overall efficiency of the large centralized generation systems is in the range of 28% to 35%, while the overall efficiency of the smaller DG systems is in the range of 40% to 55%.[8]

However, we must keep in mind that the costs and things associated with them do not decide everything. Another powerful incentive to the industrial companies to switch to DG is the improved reliability. It is common sense that it is impossible to reach lowest costs and highest reliability at the same time, but many such alternatives exist within DG. On one hand if the company's main concern is the cost, a simple DG system can be

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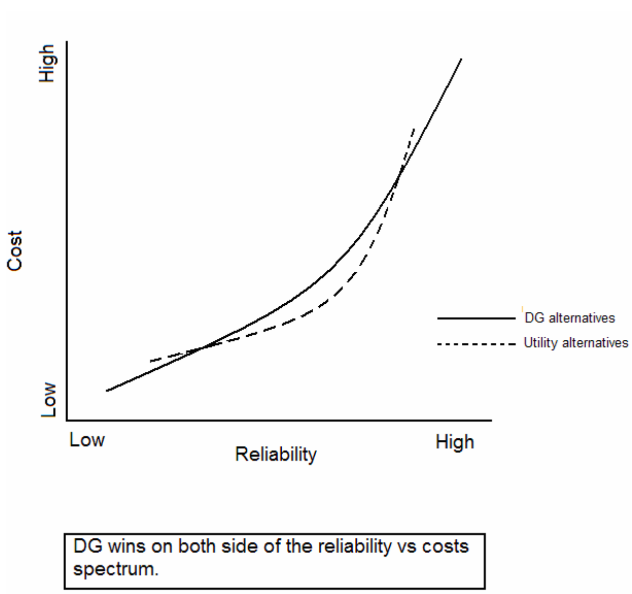
[6] Figure#2:Philipson, Lorrin, Understanding electric utilities and de-regulations, New York : M. Dekker, c1999, p. 138

[7] Quotes from: Walter G. Scott, Distributed Power Generation: Planning and evaluation, New York, M. Dekker, c2000, p8

[8] Quotes from: Walter G. Scott, Distributed Power Generation: Planning and evaluation, New York, M. Dekker, c2000, p2

installed on site, which would minimize costs, and have 95 to 98% availability (including both scheduled maintenances and unexpected failures).[9] This is of course lower than the average standard 99.97%, provided by the centralized power systems, but it would be the cheapest alternatives. However, if customer's main concern is the reliability, one can utilize *redundancy*, meaning that there would be something else to "back-up" the DG system. It can simply be additional capacity, unused in normal times, or even connection to the centralized system. Today many national electricity companies, such as N-star provide industrial consumers with the alternative to partially switch to DG, while still being connected to the grid. In this way costs will be higher, but the best efficiency will be achieved. If we had to compare DG alternatives to similar purely utility-based power alternatives, the graph, below, would summarize the situation in the best way:

Figure # 3 – Distributed generation alternatives VS Utility alternatives



[10]

[9] This, and other figures in this paragraph are taken from: Walter G. Scott, Distributed Power Generation: Planning and evaluation, New York, M. Dekker, c2000, p19

[10] Figure # 3 is adapted from: Walter G. Scott, Distributed Power Generation: Planning and evaluation, New York, M. Dekker, c2000, p10

There are two major reasons why this is true. First is that DG options are a lot more numerous, with a wider selection of equipment. This allows DG systems to be a lot more flexible, even customized for a specific customer. The second reason is that DG systems tend to be slightly more linear in combining reliability and costs, which means they have advantage on either end of the scale, as shown in the graph.

Of course DG has disadvantages, the main of which is that a lot of the technology is still unproven, meaning, that although laboratory tests show promise, it is unclear how the systems will behave in the long-term real-world usage. It is important to point out that many companies today simply will not invest in something without well-proven performance, no matter how good the incentive looks on paper. This is where our project will be useful. Today there exist many decision tools, which can help companies to make up their mind. Tools often cover these areas:

Feasibility: Although the DG systems may prove more economical in the future, one of the reasons some companies do not take advantage now is that such systems can be rather costly to install in terms of both money and time. Some companies have policies about investments, stating that if the investment requires more than X-amount of capital, it will not even be entertained as a possible action. Decision tools allow getting some kind of figure for the initial costs, if not an exact one, at least an estimate, plus. This will allow the company to see whether the worst-case scenario cost is below or above their threshold and make a better decision concerning DG.

Long-term financial issues: Some economic evaluation tools can perform a number of important calculations concerned with savings, depreciation of equipment, taxes, and other issues, while taking the time value of money into account. Again those figures might prove not exactly accurate in the future, but a general idea about such things as payback period or breakeven point can have a very decisive effect on the final decision, because just like with start-up costs, payback period thresholds are in many cases a part of the company's approval policy.

Environmental impact: Today many companies have some kind of "green" initiatives, since it can improve the image, which is an important intangible asset in places where the competition is strong. If some tools can show that installation of a certain "green" DG system can help the environment, some would consider it, even if the economical aspects do not look great.

These major and other smaller issues can be very influential on the final decision of the company on whether to install a DG system or not. The decision tools can shed some light into the dark spots, helping the company's management to come up with a better course of action. This is where our project will focus.

Legal aspects

DG can be great alternative for any company, but it is not like anybody can just switchover to DG at will. Government regulations and standards exist in order to insure proper, safe and fair use of DG. This is a serious issue, however, it is not the one regulated by the federal government, so each state has its own standards and possibilities for utilization of DG, ranging from almost none, such as in Arkansas, to many, such as in California or Texas.[11]

Because of such differences in the development of DG-related laws, it is understandable that each state has its own application and licensing processes. However,

[11] More information at: "State Regulations", Distributed Generation, 2005, Accessed 29-May-2007, < http://www.distributed-generation.com/state_regulations.htm>

there are several important regulatory issues[12], which are common to all states and must be addressed by both the providers and the consumers.

Interconnection standards deal with the connection between DG systems, the load that consumes the power and the national grids if applicable. Those standards are crucial, when it comes to mass production of DG systems. Location analysis, certification and permitting are important feasibility issues for DG systems, meaning that prior to their use by the consumer, they have to pass a number of tests, such as environmental regulations, safety features regulations, noise and aesthetic standards. Access, metering and dispatch issues concern whether the DG system can be connected to the centralized power grid, and if it can, how will the metering be regulated, whether the consumer will be able to not only buy power from the national grid in the peak of the demand, but also sell it back to the grid at a reduced/increased costs. DG system ownership is another controversial issue, which different states view differently. Some believe that DG systems have to be distributed, maintained and owned by the national electricity companies, who would provide DG opportunities to the consumers, others believe that this should be the consumer's responsibility, and thus the ownership must stay in consumer's hands. These, however are general issues, and in order to get a more specific points, we will look at Massachusetts regulations and laws, concerned with DG.

Customer seeking to install DG system on sight has to do so through an electric company, which is approved for DG contracts with individual consumers, by the Massachusetts Department of Telecommunication and Energy. The first step in this process would be a submission of application form to the company. An example of such

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[12] Classification of issues taken from: "Regulatory issues", Distributed Generation, 2005, Accessed 29-May-2007, <http://www.distributed-generation.com/regulatory_issues.htm>

application can be found on the Massachusetts' Technology Collaborative, at http://www.mtpc.org/renewableenergy/small_renewables.htm. Here it is important to notice that there are three different "review paths" (standard checks) for different equipment types:[13] Simplified Path is for qualified inverter based facilities (ones that use an inverter to convert DC into AC power), with a power rating of 10 kW or less, given that aggregate generating capacity on the DG circuit is less than 7.5% of the annual peak load. Simplified path is the quickest, consisting of the fewest hurdles. Expedited Path is for larger certified facilities that have already passed pre-specified screens on a radial system. Standard Path is for all DG facilities that do not qualify for either Simplified or Expedited path. This is the longest and most expensive path.

Table # 1 – Distributed generation review path timeframes

Review Process	**Simplified**	**Expedited**	**Standard**
Eligible Facilities	**Listed Small Inverter**	**Listed DG**	**Any DG**
Acknowledge receipt of Application	(3 days)	(3 days)	(3 days)
Review Application for completeness	10 days	10 days	10 days
Complete Review of all screens	10 days	25 days	n/a
Complete Supplemental Review (if needed)	n/a	20 days	n/a
Complete Standard Process Initial Review	n/a		20 days
Complete Impact Study (if needed)	n/a		55 days
Complete Detailed Study (if needed)			30 days
Send Executable Agreement (Note 3)	Done	10 days	15 days
Total Maximum Days (Note 4)	15 days	40/ 60 days (Note 5)	125/150 days (Note 6)
Notice/ Witness Test	< 1 day with 10 day notice or by mutual agreement	1-2 days with 10 day notice or by mutual agreement	By mutual agreement

[13] All information, including tables and of standards and regulations is taken from: "Distributed generation interconnection rules", Massachusetts Technology Collaborative: Energy Information, 16th-Feb-2007, accessed on 30th-May-2007 <http://www.mtpc.org/cleanenergy/howto/interconnection/tariffs.htm>

And here's the schedule for fees, collected along each of the paths.

Table # 2 – Distributed generation review paths fees

	Simplified	**Expedited**	**Standard**
	Listed Small Inverter	**Listed DG**	**Any DG**
Application Fee (covers Screens)	0 (Note 1)	$3/kW, minimum $300, maximum $2,500	$3/kW, minimum $300, maximum $2,500
Supplemental Review or Additional Review (if applicable)	N/A	Up to 10 engineering hours at $125/hr ($1,250 maximum) (Note2)	N/A
Standard Interconnection Initial Review	N/A	N/A	Included in application fee (if applicable)
Impact and Detailed Study (if required)	N/A	N/A	Actual cost (Note 3)
Facility Upgrades	N/A (Note 4)	Actual cost	Actual cost
O&M (Note 5)	N/A	TBD	TBD
Witness Test	0	Actual cost, up to $300 + travel time (Note 6)	Actual Cost

Chapter Three

Renewable Energy Background

Renewable energy resource concern has grown as the world energy demand grows yearly. The world's reliance on nonrenewable resources has challenged science and technology, to consider alternative energy sources as a means to reduce the reliance on fossil fuels. Today, there is a push to go green and many companies and firms are implementing renewable energy programs. To understand where energy production is going an industrial company must understand the conventional methods of energy production and nonrenewable energy sources as justification to move to alternative energy sources.

Nonrenewable energy sources include oil, gas, coal, nuclear energy, and variations of the like. Oil is primarily utilized as a fuel and exists in two forms liquid oil and oil bearing shale rock. The world's primary source of crude oil is the Middle East. Current oil reserves are estimated at 5,500 quads.[14] Over 3,000 billion barrels of oil lies in oil shale deposits around the world.[14] The technology and capitol requirements of extracting the oil shale makes it unattractive to the oil production industry and increases the world's reliance on Middle Eastern oil sources.

Coal is primarily used as for heating applications and electric power generation. Coal exists in four forms: anthracite, bituminous coal, sub-bituminous coal, and lignite. There exist over 6 times as much coal sources as oil sources making coal the most widely available energy source. Coal produces at most two-thirds the energy of oil. The world's coal reserves are estimated at 33,000 quads, over three times oil and gas reserves

[14] Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.3

combined.[15] Coal is an inexpensive option to oil for heating and electrical applications but comes second to oils use as a liquid fuel.

Natural Gas exists in a comparable capacity of oil reserves with at least 4,300 quads.[15] Natural gas is widely used as a heating fuel. When compared to other energy resources, natural gas is difficult to transport and has less energy per volume as compared to other resources.

Nuclear energy is produced through nuclear fission involving free moving atomic particles that release energy during fission. Nuclear energy plants produce electricity through the fission process. The power of fission comes from natural uranium and plutonium. There is an estimated 3.7 million tons of uranium, with the potential to produce 75,000 quads of electricity.[15]

Naturally occurring fossil fuels generate 84% of the world's energy; producing negative environmental impacts.[15] Environmental consequences of conventional energy production are air pollution and the affects thereof. Some of the health concerns include reduction in ozone that exposes humans to radiation, harmful gases such as carbon monoxide and the like. Pollution causes reduced visibility in the pollution haze. Carbon monoxide in the atmosphere can trap heat by reducing oxygen in the air that can lead to global warming by creating a green house effect.[16] The green house effect occurs by gases in the atmosphere absorbing or reflecting heat back to the earth. The green house effect alters the global water cycle causing increased cycles of precipitation and evaporation.

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[15] Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.5-10

[16] Figure#4: Quaschning, Volker, Understanding Renewable Energy Systems, London, Sterling, VA: Earthscan, 2005, p.93

Figure #4 Carbon-cycle box model

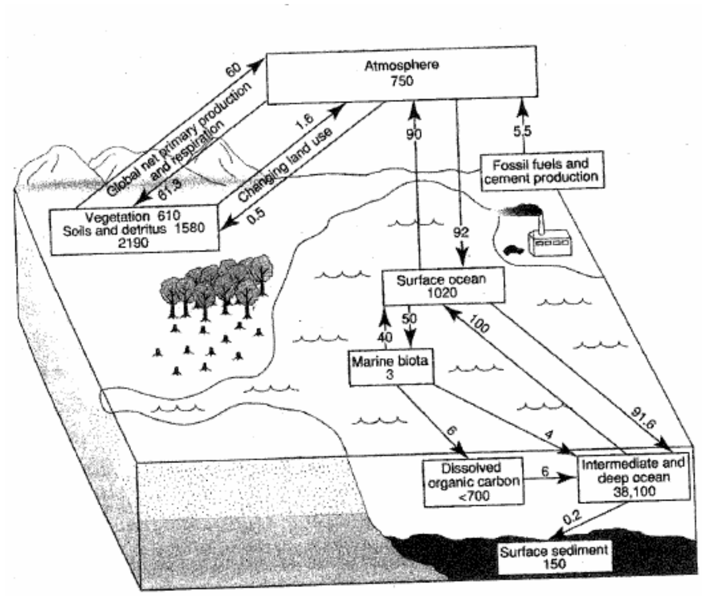

Figure 5-5. Global carbon-cycle box model [8].

The world's reliance on nonrenewable resources has driven renewable energy initiatives. There is a need to classify the several terms used to describe non-fossil energy. Renewable energy sources are defined as sources that replenish themselves; examples are wind, water, and solar sources. Renewable does not explicitly mean nonpolluting as many renewable energy sources do involve some pollution in the form of waste products and the like. Alternative energy means non-conventional but does not ensure that energy is produced by renewable resource. Alternative energy types include solar, wind, geothermal, fusion and ocean energy. Alternative like renewable energy does not explicitly mean a nonpolluting energy source. Green energy refers to energy that is clean and often using nonpolluting common resources like windmills and solar cells. Green energy does not mean renewable energy but often comes from a renewable source. Alternative energy factors include, cost, reliability, environmental impact, generating capacity, efficiency, storability, and technological limitations. In discussing alternative energy options these terms will be used to distinguish the types of energy. [17]

Renewable energy resources are used by utilities and non-utilities. Large utilities often reject renewable energy initiatives because of the instability of consumer demand, and due to the large capital costs involved. Non-utilities include industrial firms that look to renewable as a means to increase reliability, reduce conventional utilities reliance, reduce energy transmission costs, and reduce self-generated wastes. A renewable energy initiative depends on two main factors location and quality of the energy source. Rise in electricity competition for customers makes conventional electricity production appear more attractive in regard to short-term costs while renewable energy resources have a higher potential for long term cost benefits.[18] Current alternative energy resources will be discussed with a focus on wind and solar power systems.[19]

Table#3 Annual energy production for renewable energy sources

Table 7-2 Electricity generation (TWh) in the United States from renewable energy 1998–2002 [1]

Energy Type	Year 1998	1999	2000	2001	2002	m.a.g.r. (%/a)
Hydroelectric	323.3	319.5	275.6	217.0	263.6	−7.95
Solar	0.5	0.5	0.5	0.5	0.5	2.53
Wind	3.0	4.5	5.6	6.7	10.5	29.0
Biomass	58.8	59.6	60.7	57.0	59.4	−0.25
Geothermal	14.8	14.8	14.1	13.7	13.4	−2.78
Total renewable	400.4	399.0	356.5	294.9	347.5	−5.86

Hydroelectric power is produced by a renewable source and is considered a conventional energy source, capturing river water in a reservoir and letting water fall through turbines to produce electricity produce hydroelectricity. Hydroelectricity is a low

[17] Berinstein, Paula, Alternative Energy: Facts, Statistics, and Issues, Westport, CT: Oryx Press, 2001, p.8

[18] Table#3: Kruger, Paul, Alternative Energy Resources: The Quest for Sustainable Energy, Hoboken, New Jersey: John Wiley & Sons, Inc., 2006, p.139

[19] Berinstein, Paula, Alternative Energy: Facts, Statistics, and Issues, Westport, CT: Oryx Press, 2001, p.34

cost renewable source and is clean for the environment. Currently hydropower is the largest renewable energy resource producing half of the U.S. renewable energy consumption and supplying 4% of U.S. energy demand.[20] Drawbacks include its impact on wildlife and the surrounding environment in the form of thermal and air pollution. Hydroelectric plants are very dependant on the weather and the season to generate electricity. The limitations of hydroelectricity are deeply rooted in licensing and regulatory issues as well as negative environmental impacts. With limited U.S. hydroelectric sites and harsh regulations there has been a decline in hydroelectricity generation.[21]

Geothermal energy is clean in that no water or air pollution is produced and all waste remains underground where it cannot harm the environment. Geothermal is regional and resources can be used locally and supports a stable local economy. Geothermal energy is recovered in four native states: hydrothermal, hot dry rock, magma, and geopressured brines. The most common form of geothermal energy is hydrothermal energy that consists of using hot water reservoirs, as a means to heat and generate electricity.[21] Hot dry rock energy production involves pumping water into the hot rocks producing steam and hot water. Hot dry rock technology is experimental in that rock temperature increase on average 40 degrees C per mile, which would require extensive drilling and pumps to transport the heated water product.[22] Magma energy involves drilling more than 20 miles into the earth or finding magma pocket miles underground. Magma is on average over 1000 degrees C, and transportation and storage of this magma

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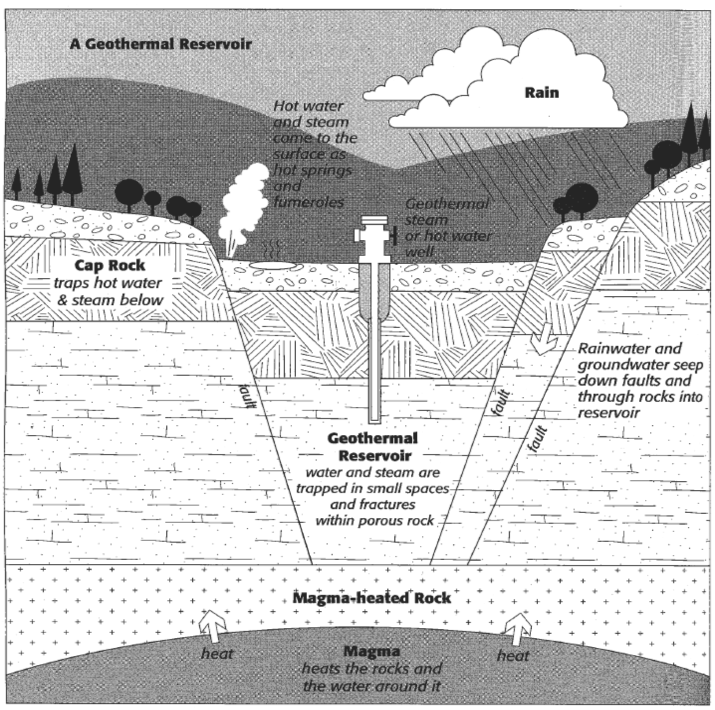
[20] Berinstein, Paula, Alternative Energy: Facts, Statistics, and Issues, Westport, CT: Oryx Press, 2001, p.27

[21] Figure#5: Cole, Nancy, Skerrett, P.J., Renewables Are Ready: People Creating Renewable Energy Solutions, Vermont: Chelsea Green Publishing Company, 1995, p.200

[22] Cole, Nancy, Skerrett, P.J., Renewables Are Ready: People Creating Renewable Energy Solutions, Vermont: Chelsea Green Publishing Company, 1995, p.199-203

would be a challenging endeavor. It is speculated that 0.5 cubic mile of magma could power a 1000 megawatt power plant for three decades.[23] Geopressured brines are underground wells that contain hot water under pressure and hydrocarbon gases. Heat energy is recovered from the brines and transported by a water pump to the surface. The advantage of geopressured brines is that it can be recovered only meters underground instead of miles like other geothermal resources. The limitations of Geothermal energy production is that the sources are scattered and is not a constant source of energy as wells can be emptied. U.S. geothermal production is limited by the fact that most geothermal locations lie in protected national park lands that would cause many regulatory issues.[23]

Figure#5 Geothermal energy model



Biomass involves taking the energy stored in plants and natural waste products and transforming the energy into power. The biomass process conventionally involves burning or heating biomass resources by breaking chemical composition of organic material. Biomass has two main categories of production biochemical conversion and thermo-chemical conversion.[23] Biochemical process uses anaerobic digestion to produce fuels such as bio-ethanol, bio-diesel, and bio-oils. Thermo-chemical production has five areas: combustion, steam cycle, liquefaction, gasification and pyrolysis. Combustion is used primarily in direct heat applications, where heat energy is created. Steam cycle production is used in electric power generation, like geothermal energy production, steam powers a generator and electricity is produced. Liquefaction process produces bio-fuel for transportation through hydrolysis and fermentation. Gasification and pyrolysis through gas conditioning and synthesis produce hydrogen, and fuel products.[24]

Figure#6 Bio-energy refining process

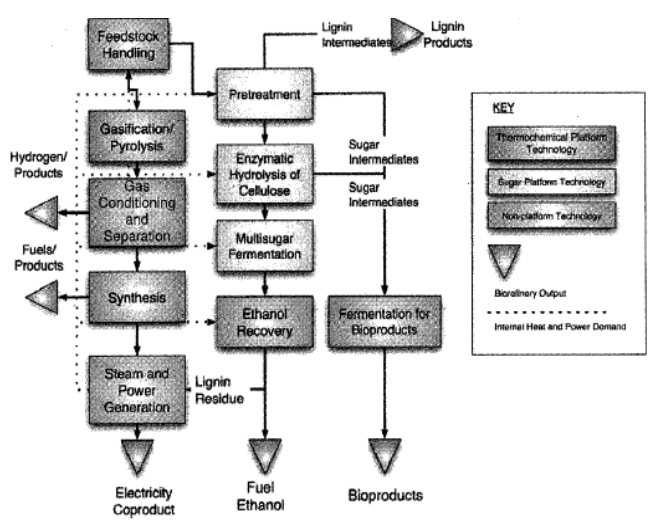


Figure 7-15. Schematic of an integrated biorefinery (from [18]).

[23] Kruger, Paul, Alternative Energy Resources: The Quest for Sustainable Energy, Hoboken, New Jersey: John Wiley & Sons, Inc., 2006, p.158-163

[24] Figure#6: Kruger, Paul, Alternative Energy Resources: The Quest for Sustainable Energy, Hoboken, New Jersey: John Wiley & Sons, Inc., 2006, p.162

The benefits of Biomass energy production are mostly air pollution reduction, in transportation and industrial industries. Bio-fuels dramatically reduces carbon emissions in the fuel cycle and because of this the EPA now requires a certain percentage of biomass produced ethanol to be added to gasoline. Municipal bio-energy initiatives reduce odors and gases in the air, and provide electricity and heat for municipal applications.

Solar Thermal energy is based on harvesting the sun's energy. The sun is the world's primary renewable energy source. The sun's rays create solar energy, that melts ice caps and produces large amounts of water for use by hydroelectricity, and ocean thermal energy. The sun is a primary element for plant growth, used to produce biomass energy through crop production. Solar energy is a term used to refer to energy that can be traced back to the sun.[25]

Solar heating, cooling, and lighting offer a means to reduce energy reliance on conventional energy sources. Two means, passive solar heating and active solar heating, can achieve solar heating. Passive solar heating involves harvesting the suns energy to reduce a buildings energy cost by providing daily heating, cooling and lighting. This is primarily done through the use of glass windowpanes. Glass allows light to pass through and also traps infrared radiation as heat energy. Solar energy is stored in materials such concrete brick, water, rock, and other materials that undergo temperature changes. In home applications insulation is used for two means to trap heat and to keep cool air out. Solar heating can be achieved in three ways: direct-gain, indirect gain, and isolated-gain systems. Direct-gain systems use glass to pass energy directly into areas. Indirect-gain

[25] Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.80-86

systems store heat energy in materials such as walls and floors. Isolated gain systems gain and store energy in a separate location from the living space, such as a green house or sunroom and transports energy through vents.[28]

Active solar heating systems utilize the sun heat to power hot water systems. These systems use light absorbing solar panels surrounded by a fluid to heat that liquid. This heated water can be used directly as a hot water source or can be stored in tanks for later use. These systems are called active solar systems as they involves actively moving the liquid to heating systems. Two common active based water systems are open loop and closed loop. In open loop systems heat water is used directly for plumbing systems.[26] Closed loop systems are a stand-alone system not connected to plumbing but store-heated water for later use.[27]

Figure#7 Solar-thermal energy system

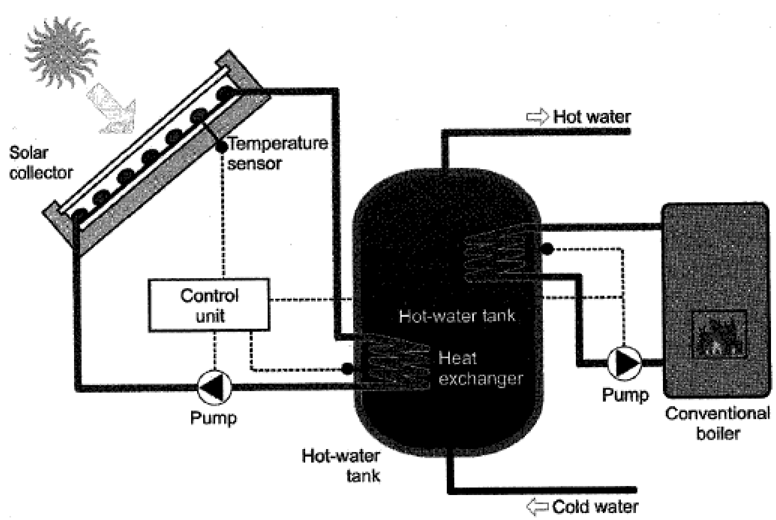


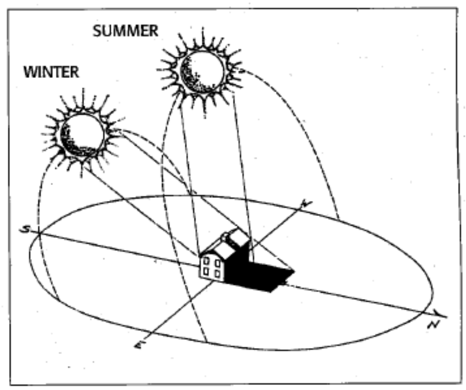
Figure 3.4 *Schematic of a Double-Cycle System with Forced Circulation*

[26]Figure#7: Quaschning, Volker, Understanding Renewable Energy Systems, London, Sterling, VA : Earthscan, 2005, p.85

[27] Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.83-89

Passive solar cooling involves shielding areas from the sun's rays. This is achieved by careful angling of awnings and shades. By doing this heat energy is reduced but light is still allowed to enter the building. This process allows the higher summer sun to be shaded and allows the lower winter sun to enter an area.[28] Aluminum foil is used in warm climates under building materials to reduce radiation heating by up to 95 percent as reported by the Florida Solar Energy Center.[31]

Figure#8 Sun cycle from winter to summer



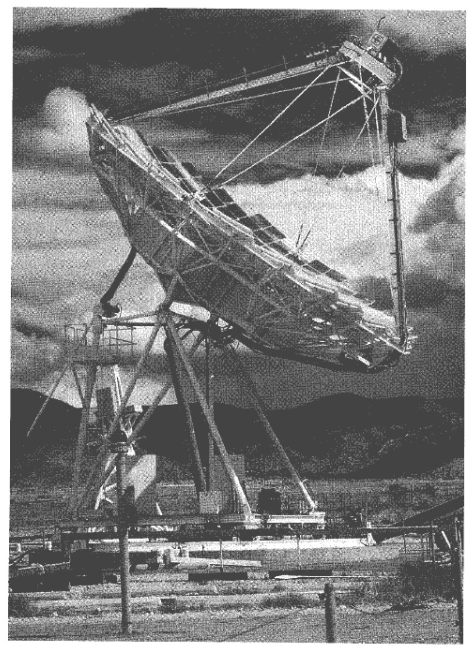
Active solar cooling involves processes that constantly work to reduce building heat. Two common methods to achieve active cooling include underground cooling tubes and the use of desiccant cooling systems. Earth cooling uses underground pipes buried deep in cool soil that use fans to take hot outside air and convert it into cool air by passing it through the cool soil. The cool air is then pumped into the building through air ducts. This process is efficient as soil temperature remains constant year round. Desiccants dehumidify and cool air by using silicon gels and salt compounds to absorb the suns energy and evaporate water to provide cool dry air.[29]

Solar Thermal Electric systems generate electricity by concentrated or distributed energy systems. In a concentrated system, mirrors and reflectors concentrate the suns rays

[28] Figure#8: Cole, Nancy, Skerrett, P.J., Renewables Are Ready: People Creating Renewable Energy Solutions, Vermont: Chelsea Green Publishing Company, 1995, p.183

on a central power tower. In distributed solar systems, parabolic dishes are spread across an area and focus light on multiple sources.[29] Solar thermal systems primarily utilize heat energy reflected by the mirrors to heat rocks, oil, and salts, for use in steam production. The steam generated from the heat and fluid interactions fuel electricity generators. Another means of solar thermal energy production involves using salt filled bodies of water to store and heat water for direct usage and for steam production for electricity generation.[30]

Figure #9 Parabolic dish focused light system



Photovoltaic systems involve converting sunlight into electricity. Photovoltaic systems range from megawatt public electricity supply systems to powering wristwatches and pocket calculators. Photovoltaic systems use semiconductors that are primarily located in-group four of the periodic table. The most common material for photovoltaic

[29] Figure #9: Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.100
[30] Golob, Richard, Brus, Eric, The Almanac of Renewable Energy, New York: Henry Holt and Company, Inc., 1993, p.89-103

instillation is silicon. Silicon molecules are arranged so all electrons fill the valence shell.[31]

Figure#10 Silicon molecule arrangements

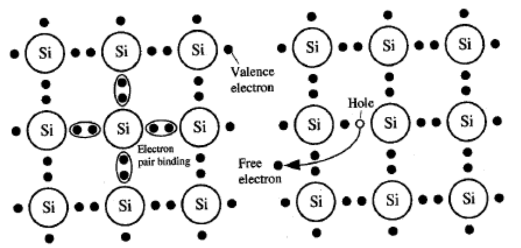


Figure 4.5 *Crystal Structure of Silicon (left), Intrinsic Conduction due to Defect Electron in the Crystal Lattice (right)*

When light or heat is applied to silicon molecules, free electrons are released. The release of these electrons is what produces photovoltaic energy. The production of solar cells and solar modules involves various crystalline silicon structures. Three principle grades of silicon are used for solar cells: metallurgical, electronic, and solar. Silicon slices called wafers are cleaned and processed to make solar cells. This process involves a series of chemical steps including: Hydrofluoric acid, phosphorus and born treatments, gas diffusion, and etching.[32] Once the wafer is processed front and rear metallic contacts are added as well as an antireflective coating. Solar wafers are laminated and then placed into junction boxes to protect the cells.[33] Photovoltaic solar cells are primarily connected in series and current flows across the rows of cells in a linear manner. Parallel connection exists but is not as widely used because of the higher transmission loss than solar panels connected in series. [32] Photovoltaic systems provide a clean portable renewable electricity

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[31] Figure #10: Quaschning, Volker, Understanding Renewable Energy Systems, London, Sterling, VA : Earthscan, 2005, p.121
[32] Quaschning, Volker, Understanding Renewable Energy Systems, London, Sterling, VA : Earthscan, 2005, p.115-147
[33] Figure #11: Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.164

source. The limitations of Photovoltaic electricity production are its reliance on the sun, weather conditions, and seasons.

Figure#11 Photovoltaic cell

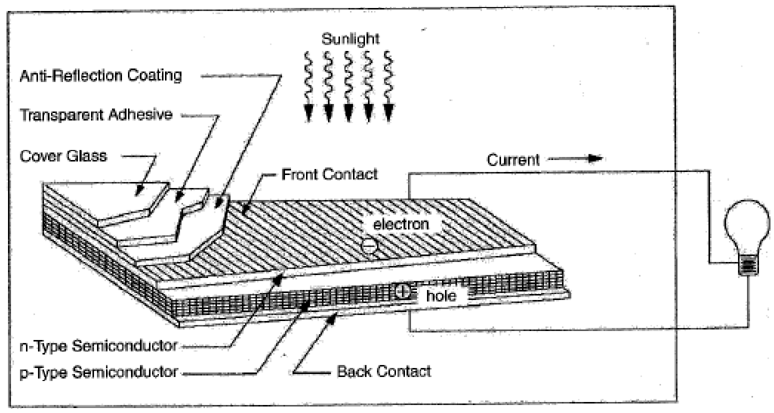


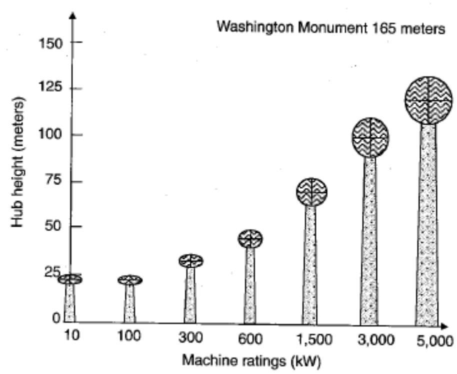
FIGURE 9.2 Basic construction of PV cell with performance-enhancing features (current-collecting silver mesh, antireflective coating, and cover-glass protection).

Wind power works by capturing moving air and using it to power a generator. No matter the size of the wind turbine all wind power devices work in one of two ways. One uses a motorized rotor that operates at a constant rate regardless of wind speed. The other type is manually driven by variable wind speed. Primarily anemometers measure wind speeds and wind patterns. Ultrasonic anemometers measure wind speed and direction by using a two axis design four fixed sensors. Measurements are taken every two seconds for 10 minutes and 10 minute averages of 300 data points are provided for analysis.[34] Optical wind speed sensors represent new technology that will improve wind speed measurement. Optical sensors measure crosswind speeds over large distances (approx. 100m) by using a helium-neon laser. The laser is reflected by sensors and provides a more precise wind measurement than conventional anemometers.

[34] Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.31-33

Wind power systems consist of three main components: tower, turbine, and rotors. The tower's primary purpose is to elevate the wind turbine to a specified height. Atop the tower sits the nacelle which houses all the parts including the gearbox allowing the wind turbine to function. Towers are generally made equal to the rotor diameter. Wind towers must be at least 25 meters high to avoid building interference, in utility applications towers are in the 50-meter range.[35]

Figure#12 Wind tower height vs. power output



Challenges of tower design include tower vibration, resonance frequencies, and transportation. Wind turbines are designed to range from less that one kilowatt to greater than five mega watts.[36] Wind turbines in general consist of two or three blades that use airfoils to capture wind. By applying the Bernoulli principle lift force is created as well as drag forces. In designing turbine blades, higher lift-to-drag ratios are desired. By using tip speed ratio (TSR) rotor efficiency can be determined to maximize power output.

Wind power as a renewable energy source is mainly geographical and varies greatly by altitude and location. Wind grade scales are used to categorize regions based

[35] Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.63-74
[36] Figure#12: Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.66

on average wind speed and altitude.[37] In general, higher altitudes have high wind speeds. In the U.S. wind power generation initiatives are most feasible in the Mid-western region. Other locations such as the Southern and Northeastern regions have variable locations of wind feasibility.[38]

Table#4 Wind classification

TABLE 3.5
Wind Energy Resource Classification with Wind Classes of Power Density

	10 m (33 ft) Hub		30 m (98 ft) Hub		50 m (164 ft) Hub	
Wind Class	Wind Power Density W/m²	Speed[a] m/s (mph)	Wind Power Density W/m²	Speed[a] m/sec (mph)	Wind Power Density W/m²	Speed[a] m/sec (mph)
1	100	4.4 (9.8)	160	5.1 (11.4)	200	5.6 (12.5)
2	150	5.1 (11.5)	240	5.9 (13.2)	300	6.4 (14.3)
3	200	5.6 (12.5)	320	6.5 (14.6)	400	7.0 (15.7)
4	250	6.0 (13.4)	400	7.0 (15.7)	500	7.5 (16.8)
5	300	6.4 (14.3)	480	7.4 (16.6)	600	8.0 (17.9)
6	400	7.0 (15.7)	640	8.2 (18.3)	800	8.8 (19.7)
7	1000	9.4 (21.1)	1600	11.0 (24.7)	2000	11.9 (26.6)

Source: From Elliott, D.L. and Schwartz, M.N., Wind Energy Potential in the United States, Pacific Northwest Laboratory PNL-SA-23109, NTIS No. DE94001667, September 1993.

Figure#13 Wind area densities

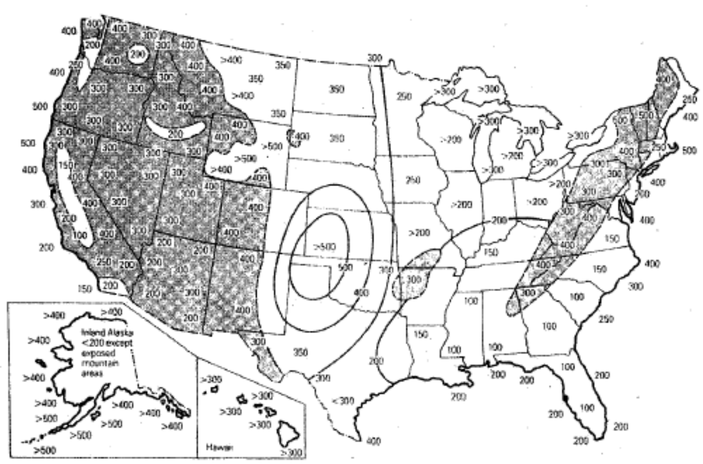


FIGURE 3.17 Annual average wind power density in W/m² in the U.S. at 50-m tower height. (From DOE/NREL.)

Wind power is a green energy technology producing no air pollution or waste products. Wind power is modular and can be placed in almost any location where wind

[37] Table#4: Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.49
[38] Figure#13: Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.50

potential exists. The limitations of wind power is that it is largely location based and can require large amounts of space for power generation.[39] Extensive research into wind power feasibility on a site must be conducted. Wind energy compared to conventional energy generation methods has the shortest energy payback rate.[40] Power generation is all based on wind variations that can be influenced by weather patterns, seasons, and lunar cycles. Wind turbines alone are relatively quiet and produce a low audible sound. Large wind farms on the other hand produce a lot of noise, and are visually impairing Because of this local governments have zoning policies in place that prevent large scale wind power application in or near residential locations.[41] The environmental impacts are large in the sense that wind power turbines can be dangerous to wildlife. These factors must be extensively analyzed prior to a wind power initiative.

Figure#14 Wind tower spacing diagram

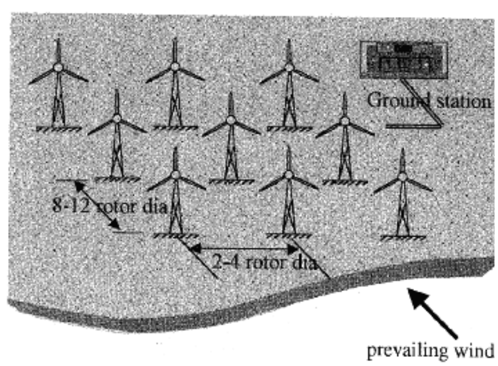


FIGURE 4.14 Optimum tower spacing in wind farms in flat terrain.

Figure#15 Energy payback in years

Fig. 6.4. Energy Payback Ratio of various energy sources

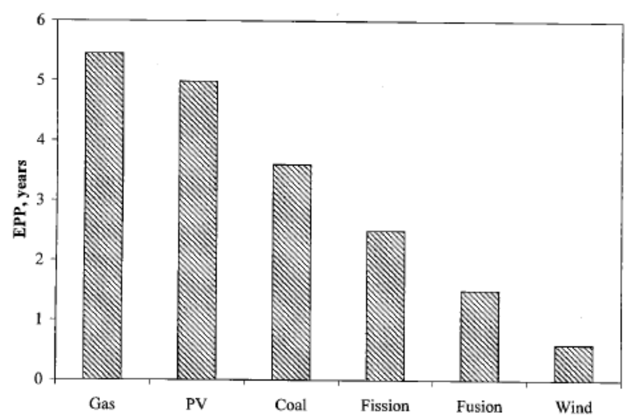


Fig. 6.5. Energy payback period of various energy sources

[39] Figure #14: Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.77
[40] Figure#15: Mathew, Sathyajith, Wind Energy: Fundamentals, Resource Analysis and Economics, Berlin, Heidelberg, Netherlands: Springer-Verlag Press, 2006, p.188
[41] Patel, Mukund R., Wind and Solar Power Systems: Design, Analysis, and Operation SE, Boca Raton, FL: CRC Press Taylor & Francis Group, 2006, p.82-84

Chapter Four

Internet Based Tool Descriptions

There are five different decision tools that we would like to evaluate. The tools' names are: "Small Wind Toolbox", "PV Watts", "My Solar Estimator", "Simple Financial Model" and "Wind Energy Project Model". Two are Excel-based and three are Internet-based. We would like to make our main emphasis on comparison between those two types.

American Wind Energy Association (see www.awea.org) provides a guide for 100kW wind projects and (see http://www.awea.org/smallwind/toolbox/INSTALL/default.asp) provides guidance to install wind power systems and promote them. Installing toolbox provided evaluation, financing, permits, and connection advice. Promotional toolbox provided zoning information, wind power market evaluations, utility connections, and incentives of wind power systems.

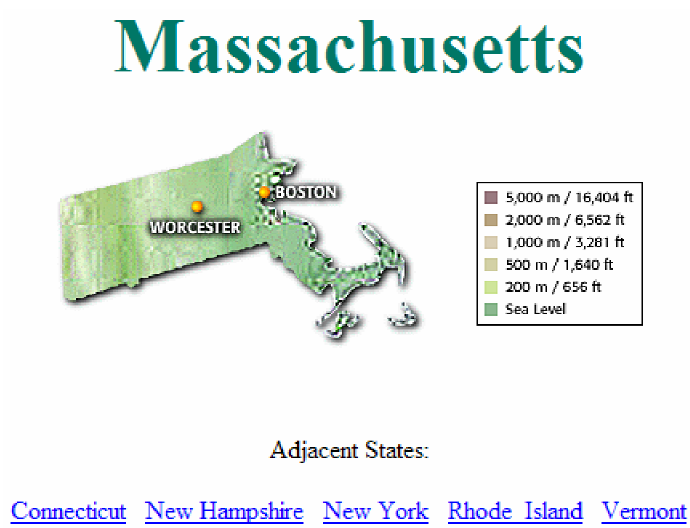
Figure # 16 – Small Wind Toolbox Screenshot 1

Small Wind Toolbox provides more of a step-by-step guide to wind energy systems;

however, it doesn't offer exclusively a calculator to evaluate a wind system.

Renewable Resource Data Center (see http://rredc.nrel.gov/) provides **PV Watts international site performance calculator** for grid connected Photovoltaic systems (see page 27 for description on PV) serving all seven continents (see http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/). The user inputs information on continent, country, and state and the program shows adjacent states to the site and elevation charts measured in miles and feet.

Figure # 17 – Small Wind Toolbox Screenshot 2



Input

First, the user selects one of the major counties in the state, closest to the user's site and inputs the DC rating of the system in kW. Next step is the input of the system specifications, such as DC rating, cost of electricity, array type, and others, shown above. All these values have default presets, however, the user can change any of these at will, if the system is non-standard.

Figure # 18 – Small Wind Toolbox Screenshot 3

Station Identification:

WBAN Number:	94746
City:	Worcester
State:	MA

PV System Specifications:

DC Rating (kW):	4.0	
DC to AC Derate Factor:	0.77	DERATE FACTOR HELP
Array Type:	Fixed Tilt	
Fixed Tilt or 1-Axis Tracking System:		
Array Tilt (degrees):	42.27	(Default = Latitude)
Array Azimuth (degrees):	180.0	(Default = South)

Energy Data:

Cost of Electricity (cents/kWh):	Default = State Average

Output

The tool provides the monthly data on Solar Radiation (kWh/m^2/day), AC Energy (kWh), and monthly energy value ($), and computes average yearly solar radiation, yearly AC energy, and yearly energy value.

Figure # 19 – Small Wind Toolbox Screenshot 4

Station Identification	
City:	Worcester
State:	MA
Latitude:	42.27° N
Longitude:	71.87° W
Elevation:	301 m
PV System Specifications	
DC Rating:	4.00 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.08 kW
Array Type:	Fixed Tilt
Array Tilt:	42.3°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	11.8 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	3.37	338	39.88
2	4.35	396	46.73
3	4.84	466	54.99
4	4.86	437	51.57
5	5.26	467	55.11
6	5.34	444	52.39
7	5.60	479	56.52
8	5.31	456	53.81
9	4.94	419	49.44
10	4.32	401	47.32
11	3.20	298	35.16
12	2.87	281	33.16
Year	4.52	4883	576.19

Strengths:

PV Watts can be used for any location in the world near limited major territories. It provides an accurate estimate for energy produced at a specific site. By default estimates for a 4.00kW system, system sizes range from les than 1 kW to a few MW.

Weakness:

The estimation data points are for a small number of territories. In the case of Massachusetts, it only has two locations, Worcester and Boston as sample points. This software if extended to more regions in an area could be more useful for small solar applications in more remote areas farther from the major territories.

Find Solar.com - Find a Solar Pro

This useful website, http://www.findsolar.com/index.php?page=findacontractor, provides contact information of solar contractors as well as a solar system calculator.

Inputs

In case a user want to find a professional in the solar systems, this tool can be very helpful. Search can be done by different methods, such as U.S. or Canada location, solar contractor name, or distributor or manufacturer name, or by offer specific renewable services.

Outputs

The tool returns contractor's contact information and solar related services offered by the contractor in alphabetical order. Findsolar.com also has a number of criteria in which a potential solar customer can search by to further distinguish between solar installers.

Figure # 20 – Find a Solar Pro tool screenshot

Find Solar.Com - My Solar Estimator

The same website also provides a solar calculator.

http://www.findsolar.com/index.php?page=rightforme

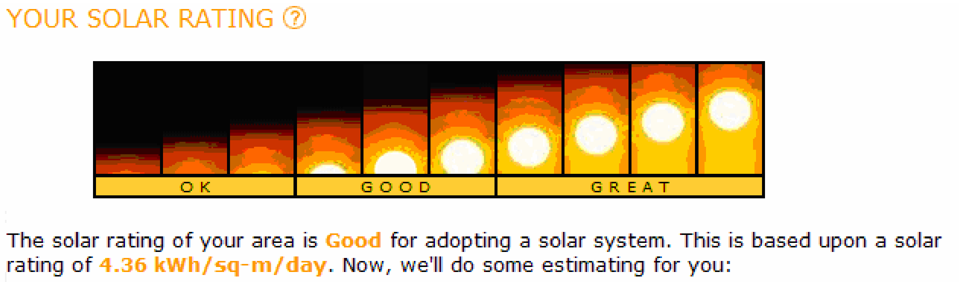
Inputs

The user selects Select U.S. State, Select County in state.

Outputs

The tool provides solar rating for a specified area and solar rating measured in kWh/sq-m/day and rates in on the scale of OK-Good-Great.

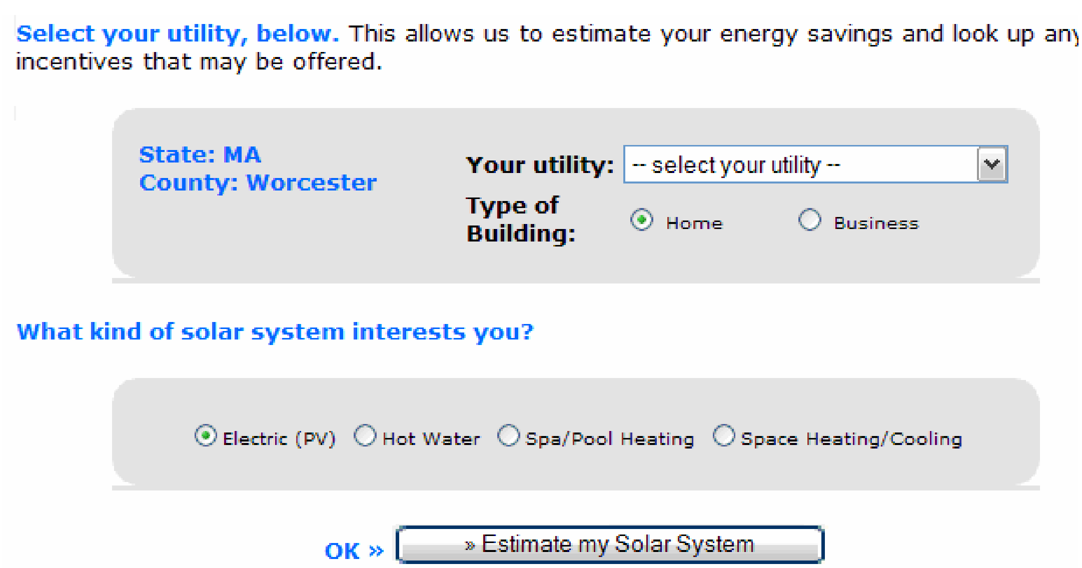
Figure # 21 – My Solar Estimator screenshot 1



Inputs

Next, the user selects the Utility providers in the county, and chooses the type of building the system is going to be used at: either a home or a business. User also must choose the type of solar system requested: Electric (PV), Hot water, Spa/pool heating, Space Heating/Cooling. Input the cost based on a monthly electric bill, or yearly kW hours, or by seasonal electric bill.

Figure # 22 – My Solar Estimator screenshot 2



Outputs

The tool computes the solar estimate to provide a desired percentage of electricity needs. The outputs display: Building type, State & County, Utility, Utility type, Average electric rate in $/kWh (this can be recalculated base on actual bill data), Average Monthly

Electricity Usage (this can be recalculated base on actual bill data), Average monthly electricity bill in-terms of dollar per month. It estimates solar system size in peak power measured in kW, displays solar rating one more time, shows solar system capacity required to meet the required percentage of energy demand. Roof area needed is also estimated in sq-ft. proportional to kW of solar system.

Figure # 23 – My Solar Estimator screenshot 3

Building Type:	Commercial/Business
State & County:	MA - Worcester
Utility:	NSTAR
Utility Type:	Investor-Owned Utility
Assumed Average Electric Rate: Please check against your bill To recalculate, enter a value and press "enter" on your keyboard - More	$ 0.0814 /kWh
Assumed Average Monthly Electricity Usage: Please check against your bill To recalculate, enter a value and press "enter" on your keyboard - More	3,071 kWh/Month
Your Average Monthly Electricity Bill: (Assumed rate x average monthly useage)	$ 250 / Month

The system size best for your situation will vary based upon product, building, geographic and other variables. We encourage you to work with a Solar Pro who can better estimate the system size best for your situation. We estimate your building will need a system sized between 13.20 kW and 19.80 kW of peak power. This estimate assumes the mid-point of this range.

Solar Rating:	**Good** (4.36 kWh/sq-m/day)
Solar System Capacity Required: This Estimator is designed for residential and commerical PV systems less than 10kW in size. We encourage you to work with a Solar Pro who can better estimate your needs and incentives available to you.	16.50 kW of peak power (DC watts)
Roof Area Needed:	1,650 sq-ft

The tool displays the assumed Installation costs, but this value can be recalculated, if the user wishes to change the $/watt ratio. It displays expected state rebates, state tax credit deductions, and federal tax credits and produces an estimated net cost of the system installation taking rebates and credits into account.

Figure # 24 – My Solar Estimator screenshot 4

Assumed Installation cost: (before rebates, incentives or tax credits). See the Cost Notes, below! To recalculate, enter a value for assumed cost/watt installed and press "enter" on your keyboard.	**$148,500** assuming $ 9 /watt
Expected NSTAR Utility Rebate: (Limited to not exceed state max. incentive amount)	($ 0)
Expected MA State Rebate ($2/watt installed) (Maximum: $20000)	($ 20,000)
MA State Tax Credit/Deduction (15% of net system cost) (Maximum of $1000)	($ 1,000)
Federal Tax Credit: (Installation type: Business)	($ 44,550)
Income Tax on Tax Credit:	$ 280
YOUR ESTIMATED NET COST: This Estimator is designed for residential and commercial PV systems less than 10kW in size. Cost and incentive data for larger systems may not be correct. We encourage you to work with a Solar Pro who can better estimate your needs and incentives available to you.	**$ 83,230**
Monthly Payment (6.5% apr, 30 years):	$ 526

Output Savings and Benefits

It reports property value increase form solar system instillation, utility savings, estimated investment return percentage, break-even analysis for investment, and environmental benefits in terms of greenhouse gas reductions.

Figure # 25 – My Solar Estimator screenshot 5

Increase in Property Value:	**$26,560 to $66,892**	More	
Exempt from Property Tax:	**YES**	More	
Accelerated (5 yr) Depreciation: (Installation type: Business)	**YES**	More	
First-year Utility Savings:	**$1,328 to $3,345**	More	
Average Monthly Utility Savings: (over 25-year expected life of system)	**$186 to $468**	More	**Assumed Utility Inflation Rate** 3.78 %
Average Annual Utility Savings: (over 25-year expected life of system)	**$2,229 to $5,614**	More	To recalculate, enter a value and press "enter" on your keyboard
25-year Utility Savings:	**$55,725 to $140,344**	More	
Return on Investment (ROI): (with Solar System ave. cost set as asset value)	**196%**	More	
Return on Investment (ROI): (with Property appreciation set as asset value)	**615% to 244%**	More	
Years to Break even: (Includes property value appreciation)	**2 to 15 years**	More	
Years to Break even: (Assuming no property value appreciation)	**9 to 22 years**	More	
Greenhouse Gas (CO2) Saved: *over 25-year system life*	**378.0 tons (756,000 auto miles)**	More	

Strengths

My solar estimator provides detailed estimation for a solar initiative. This estimator takes only a few parameters mainly location data and some general electricity usage data to compile the estimation. Estimation compares favorably with many excel based programs in its details and clarity. Overall Find Solar.com provides an in-depth access to solar installers but also extensive solar system data with a focus on the economics of a solar decision.

Weakness

With the different parameter change options that a user can access with this software, it is easy to alter a solar recommendation based on limited parameters which may influence the feasibility of a project. If this software included feasibility range calculator it would be a more complete estimator as compared to excel based systems.

Excel Based Tool Descriptions

The first Excel based tool is called "**DRAFT 3.0 Non-Residential Solar Photovoltaic Project Simple Financial Model (12/06/06)**" and it is found on the www.masstech.org/cleanenergy/cando/howto.htm website. This is a financial Microsoft Excel-based cash flow and income statement calculator for the solar projects.

Inputs

Figure # 26 – Simple Financial Model screenshot 1

Key		
Entry Cells	(green)	
Calculation Cells (Not for Entry)	(white)	
Select Taxable or Non-Taxable Entity	Taxable	
Project and Customer Cost Assumptions		
Solar Photovoltaic System Size	50,000	Watts (DC STC)
Total System Cost/Watt	$ 8.50	$/Watt (DC STC)
Total System Cost	$ 425,000	
MTC Rebate Assumptions		
MTC Scenario A: Non-Taxable Rebate	$ 3.75	$/Watt (DC STC)
Scenario A Rebate	$ 187,500	
MTC Scenario B: Taxable Rebate	$ 3.75	$/Watt (DC STC)
Scenario B Rebate	$ 187,500	
Project Performance and Savings/ Cost Assumptions		
Annual Net Capacity Factor	14.0%	kW (DC STC) to kWh AC
Annual Production Degradation	0.50%	%
Project Life	25	Years
Electricity Revenue (Avoided Costs)	$ 0.14	$/kWh
Electricity Revenue (Avoided Costs) Annual Adjustor	3.0%	%
Renewable Energy Certificate (REC) Revenue	$ 0.05	$/kWh
REC Revenue Annual Adjustor	0.0%	%
REC Revenue Term	4	Years (must be equal to or less than project life)
Annual Operations and Maintenance Cost	$ 500	$/Year
Annual Operations and Maintenance Adjustor	3.0%	%
Future Inverter Replacement Cost	$ 0.75	$/Watt (DC STC)
Inverter Life, Replace Every X Years	15	Year (must be equal to or less than project life)

Those are the first columns of inputs. The good thing about this tool is that it can perform calculations for two different scenarios, depending on the MTC (Massachusetts Technology Collaborative) rebate assumptions. Scenario A: Non-Taxable Rebate - Assumes that the state rebate is non-taxable, but is subtracted from the cost basis for purposes of determining tax credits and accelerated depreciation. Scenario B: Taxable Rebate - Assumes that the state rebate is taxable, but is not subtracted from the cost basis for purposes of determining tax credits and accelerated depreciation. Under the "Renewable Energy Trust" program, MTC is offering grants and rebates to the renewable energy users. Taxable or non-taxable rebates vary between projects. More specific information can be found on http://www.masstech.org/. Other inputs ask the user to estimate such thing as project life, revenue term, net capacity factor and others.

Figure # 27 – Simple Financial Model screenshot 2

Tax Assumptions						
Federal Tax Rate	35%					
State Tax Rate	9%					
Effective Tax Rate	41%					
Federal Tax Credit	30%					
State Tax Deduction	100%					
5 Year Accelerated Depreciation Schedule (MACRS)	20.00%	32.00%	19.20%	11.52%	11.52%	5.76%
Financing Assumptions						
100% Cash or 100% Loan	Cash					
Loan Interest Rate	7%					
Loan Period	10	Years (must be equal to or less than project life)				
Scenario A Net Cost	$ 237,500					
Scenario A Loan	$ -					
Scenario B Net Cost	$ 237,500					
Scenario B Loan	$ -					
Customer Discount Rate	8%					

The second column of inputs asks for the tax and financing assumptions. It also deals with the matters of depreciation of equipment, interest rates, tax deductions and, very important in the financial matters – user's Discount rate, also known as Minimal Internal Rate of Return (MIRR).

Outputs

Since there are two different scenarios being evaluated here, the most important things the companies would usually like to know upfront are Present Value (PV) of the project and the Payback period. Therefore the tool provides those values in a separate window.

Figure # 28 – Simple Financial Model screenshot 3

Solar Project Financial Analysis Summary	
Scenario A: Non-Taxable Net Present Value	$ (32,045)
Scenario A: Non-Taxable Simple Payback	Year 13
Scenario B: Taxable Net Present Value	$ 9,999
Scenario B: Taxable Simple Payback	Year 5

However, in case the user wants a more detailed report, the tool also provides a detailed year-by-year cash flow projection and income statement.

Figure # 29 – Simple Financial Model screenshot 4

Scenario A: Non-Taxable Rebate; Pro Forma Project Economics					
INCOME STATEMENT					
Electricity Revenue (Avoided Cost)	$	8,585	$	8,798	$
REC Revenue	$	3,066	$	3,051	$
Total Revenue (Avoided Costs)	$	11,651	$	11,849	$
Operations & Maintenance Costs	$	(500)	$	(515)	$
Inverter Replacement Cost	$	-	$	-	$
Total Operating Expenses	$	(500)	$	(515)	$
EBITDA	$	11,151	$	11,334	$
Federal Depreciation Expense	$	(40,375)	$	(64,600)	$
EBIT	$	(29,224)	$	(53,266)	$
Interest Expense	$	-	$	-	$
EBT	$	(29,224)	$	(53,266)	$
Federal taxes saved/(paid)	$	10,580	$	19,000	$
State taxes saved/(paid) [can not deduct federal depreciation expense]	$	(1,004)	$	(1,020)	$
Net Income	**$**	**(19,648)**	**$**	**(35,286)**	**$**

Figure # 30 – Simple Financial Model screenshot 5

CASH FLOW STATEMENT				
Cash From Operations				
Net Income		$ (19,648)	$ (35,286)	$
Federal Depreciation Expense		$ 40,375	$ 64,600	$
Cash Flow From Operations		$ 20,727	$ 29,314	$
Cash From Investing				
Installed PV Cost	$ (237,500)			
One Time State Solar Investment Tax Deduction (Actual Cash Value)		$ 21,375		
One Time Federal Solar Investment Tax Credit		$ 71,250		
Cash Flow From Investing	$ (237,500)	$ 92,625	$ -	$
Cash From Financing				
Loan Disbursement	$ -			
Loan Repayment (Principle)		$ -	$ -	$
Cash Flow From Financing	$ -	$ -	$ -	$
Annual Cash Flow	**$ (237,500)**	**$ 113,352**	**$ 29,314**	**$**
Cumulative Cash Flow	**$ (237,500)**	**$ (124,148)**	**$ (94,834)**	**$**

Strength

The tool provides a very thorough financial analysis in terms of both income statement and cash flow. It also shows clearly if it is more profitable to have the MTC rebate taxable or non-taxable and allows for a very wide variety of options in terms of financing, depreciation and technical aspects. It is very flexible and not limited to one state. For the states, in which no rebates are offered for renewable power initiative, the rebate value can simply be set to zero. It is Excel-based, so it does not take too much space on your hard drive, runs relatively fast, and is easy to use for a person even a little familiar with Microsoft Office programs. It is efficient and will certainly not crash the system.

Weakness

The main difficulty in using this tool is that is requires a good number of very specific estimates and figures. Some of the data might not be initially available, so some research might need to be done before the tool can be used.

The next tool here is called "**Wind Energy Project Model**", produced by RETScreen International (http://www.retscreen.net/). It is a very large Excel-based program, consisting of seven different sheets.

Inputs

Figure # 31 – Wind Energy Project Model screenshot 1

RETScreen® Energy Model - Wind Energy Project — Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Wind Farm	See Online Manual
Project location		Andhra, India	
Wind data source		Wind speed	
Nearest location for weather data		Hyderabad	See Weather Database
Annual average wind speed	m/s	6.2	
Height of wind measurement	m	30.0	3.0 to 100.0 m
Wind shear exponent	-	0.16	0.10 to 0.40
Wind speed at 10 m	m/s	5.2	
Average atmospheric pressure	kPa	94.4	60.0 to 103.0 kPa
Annual average temperature	°C	27	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	1200	Complete Equipment Data sheet
Number of turbines	-	20	
Wind plant capacity	kW	24,000	
Hub height	m	70.0	6.0 to 100.0 m
Wind speed at hub height	m/s	7.1	
Wind power density at hub height	W/m²	420	
Array losses	%	3%	0% to 20%
Airfoil soiling and/or icing losses	%	2%	1% to 10%
Other downtime losses	%	2%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

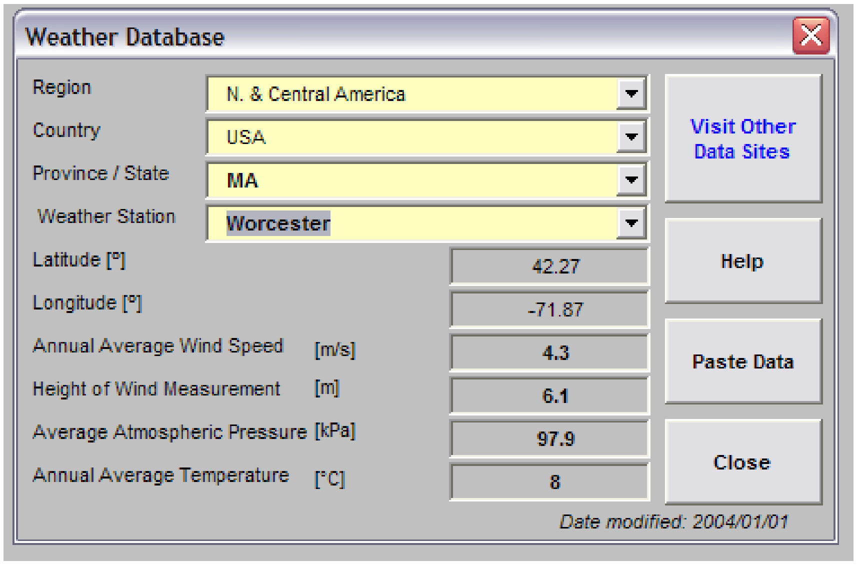
Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	1,200	24,000	
	MW	1.200	24.000	
Unadjusted energy production	MWh	2,521	50,426	
Pressure adjustment coefficient	-	0.93	0.93	0.59 to 1.02
Temperature adjustment coefficient	-	0.96	0.96	0.98 to 1.15
Gross energy production	MWh	2,251	45,020	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	888	888	150 to 1,500 kWh/m²
Wind plant capacity factor	%	19%	19%	20% to 40%
Renewable energy delivered	MWh	2,034	**40,682**	
	GJ	7,323	146,456	

Complete Cost Analysis sheet

Intro | **Energy Model** | Equipment Data | Cost Analysis | GHG Analysis | Financial Summary | Sensitivity | Sheet1 | S

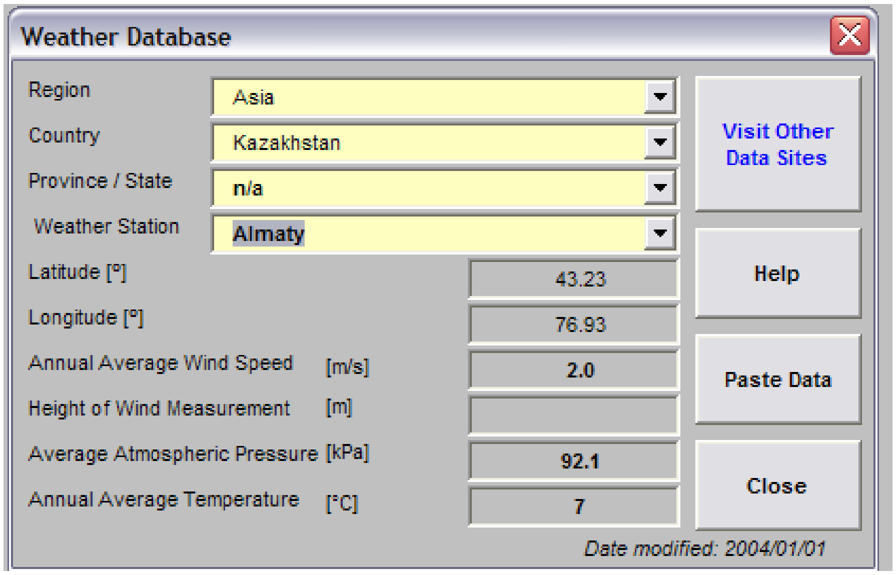
The first input sheet is concerned with the data about the system, site conditions and such. The user has the choice between Metric and Imperial units of measurement and gets to name the project. The next step would be to input the weather data and for that, the user simply has to choose the city/town, closest to the future system's location form the built-in weather database, after which the data can be auto-pasted into the worksheet.

Figure # 32– Wind Energy Project Model screenshot 2



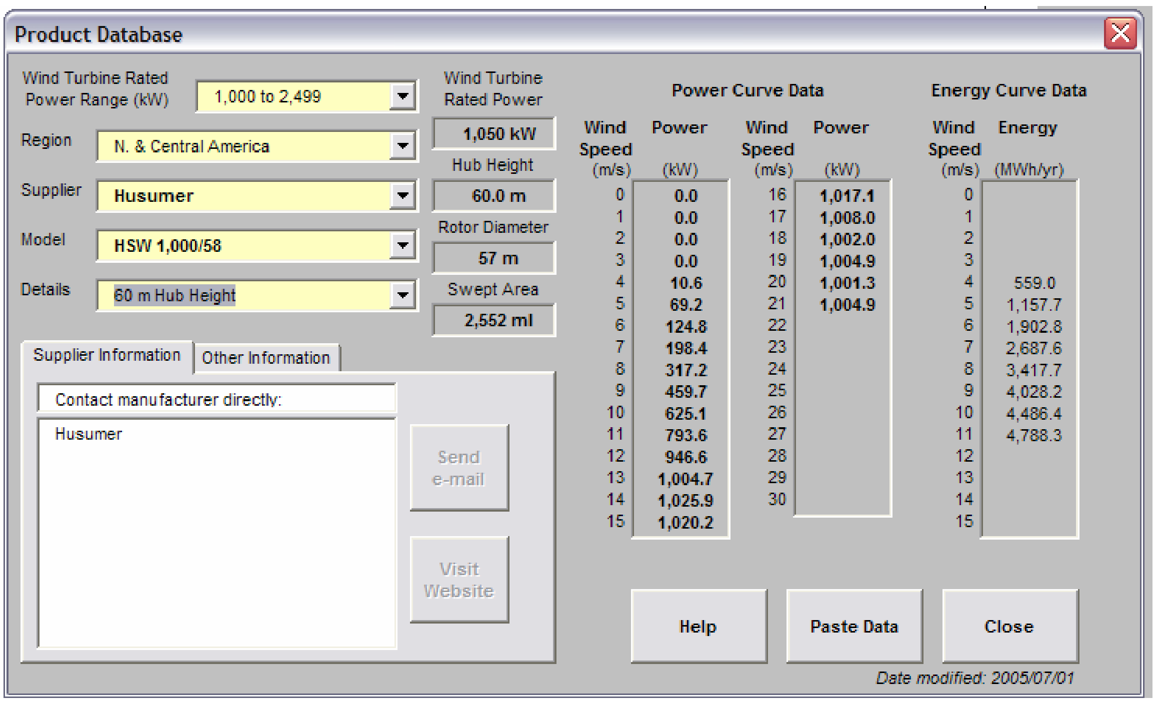
The database is not limited to Northern America and provides worldwide coverage.

Figure # 33– Wind Energy Project Model screenshot 3



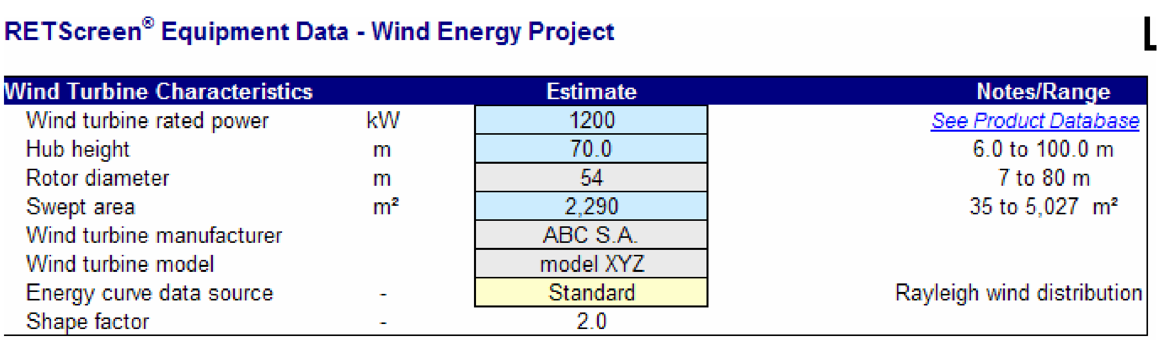
Then, the user is asked to fill out the Equipment data sheet. This can be done manually, but the program has a very impressive database of equipment, in which the user can choose the wind generator equipment by the power range, region, supplier, model and details.

Figure # 34– Wind Energy Project Model screenshot 4



The relevant data, concerning the rated power, nub height, rotor diameter, and power curve can be pasted directly into the data sheet.

Figure # 35– Wind Energy Project Model screenshot 5



If the equipment is not in the database, the values can be inputted directly into the tables.

Outputs

The outputs given by the tool are numerous. First of all, it calculates the initial costs of the project, in order to see if it is feasible at all.

Figure # 36– Wind Energy Project Model screenshot 6

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study					
Feasibility study	Cost	1	$ 245,200	$ 245,200	
Sub-total:				**$ 245,200**	0.8%
Development					
Development	Cost	1	$ 835,500	$ 835,500	
Sub-total:				**$ 835,500**	2.6%
Engineering					
Engineering	Cost	1	$ 610,500	$ 610,500	
Sub-total:				**$ 610,500**	1.9%
Energy Equipment					
Wind turbine(s)	kW	21,000	$ 1,000	$ 21,000,000	
Spare parts	%	3.0%	$ 21,000,000	$ 630,000	
Transportation	turbine	20	$ 33,000	$ 660,000	
Other - Energy equipment	Cost	0	$ -	$ -	
Sub-total:				**$ 22,290,000**	69.0%
Balance of Plant					
Balance of plant	Cost	1	$ 5,868,000	$ 5,868,000	
Sub-total:				**$ 5,868,000**	18.2%
Miscellaneous					
Contingencies	%	5%	$ 29,849,200	$ 1,492,460	
Interest during construction	6.0%	12 month(s)	$ 31,341,660	$ 940,250	
Sub-total:				**$ 2,432,710**	7.5%
Initial Costs - Total				**$ 32,281,910**	100.0%

It then gives the projection of costs and savings.

Figure # 37– Wind Energy Project Model screenshot 7

Project Costs and Savings

Initial Costs			
Feasibility study	0.8%	$	245,200
Development	2.6%	$	835,500
Engineering	1.9%	$	610,500
Energy equipment	69.0%	$	22,290,000
Balance of plant	18.2%	$	5,868,000
Miscellaneous	7.5%	$	2,432,710
Initial Costs - Total	100.0%	**$**	**32,281,910**
Incentives/Grants		$	10,000
Periodic Costs (Credits)			
Drive train		$	1,000,000
Blades		$	1,000,000
		$	-
End of project life - Credit		$	-

Annual Costs and Debt		
O&M	$	770,000
Debt payments - 15 yrs	$	3,679,049
Annual Costs and Debt - Total	**$**	**4,449,049**
Annual Savings or Income		
Energy savings/income	$	#DIV/0!
Capacity savings/income	$	24,000
RE production credit income - 10 yrs	$	#DIV/0!
GHG reduction income - 21 yrs	$	#DIV/0!
Annual Savings - Total	**$**	**#DIV/0!**
Schedule yr # 10,20		
Schedule yr # 15		

It can perform sensitivity and risk analysis.

Figure # 38– Wind Energy Project Model screenshot 8

RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

Use sensitivity analysis sheet?	Yes		Perform analysis on	After-tax IRR and ROI
Perform risk analysis too?	No		Sensitivity range	20%
Project name	Wind Farm		Threshold	15.0 %
Project location	Andhra, India			

Click here to Calculate Sensitivity Analysis

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of energy ($/kWh) 0.0760	0.0855	**0.0950**	0.1045	0.1140
		-20%	-10%	0%	10%	20%
#DIV/0!	-20%	7.2%	9.8%	12.4%	14.9%	17.6%
#DIV/0!	-10%	10.2%	13.1%	16.1%	19.2%	22.3%
#DIV/0!	0%	13.3%	16.7%	**20.1%**	23.7%	27.4%
#DIV/0!	10%	16.6%	20.4%	24.4%	28.5%	32.8%
#DIV/0!	20%	20.0%	24.4%	28.9%	33.6%	38.4%

Initial costs ($)		Avoided cost of energy ($/kWh) 0.0760	0.0855	**0.0950**	0.1045	0.1140
		-20%	-10%	0%	10%	20%
25,825,528	-20%	20.1%	24.7%	29.5%	34.4%	39.4%
29,053,719	-10%	16.2%	20.1%	24.1%	28.3%	32.6%
32,281,910	0%	13.3%	16.7%	**20.1%**	23.7%	27.4%
35,510,101	10%	11.0%	14.0%	17.0%	20.1%	23.3%
38,738,292	20%	9.1%	11.8%	14.6%	17.3%	20.1%

It can also produce Greenhouse Emission Analysis.

Figure # 39 Wind Energy Project Model screenshot 9

RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project

Use GHG analysis sheet?	Yes	Type of analysis:	Standard
Potential CDM project?	No		

Background Information

Project Information

Project name	Wind Farm	Project capacity	21.00 MW	**Global Warming Potential of GHG** 21 tonnes CO_2 = 1 tonne CH_4	(IPCC 1996)
Project location	Andhra, India	Grid type	Central-grid	310 tonnes CO_2 = 1 tonne N_2O	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Coal	50.0%	94.6	0.0020	0.0030	35.0%	12.0%	1.117
Large hydro	50.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000
Electricity mix	100%	153.6	0.0032	0.0049		12.0%	0.559

Does baseline change during project life? No

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000

Strength

The strength of this tool is in its thorough analysis, its user friendliness and its great databases that cover the entire world in terms of locations and equipment.

Weakness

Sometimes, some of the data is missing in the databases, so the analysis comes out incomplete, which somewhat decreases the tool's value.

Chapter Five

After taking a detailed look at each of the tools, we need to develop a way to compare them. We believe a scoring model is the best means to perform the evaluation. The scoring model works by developing the evaluation criteria, and then assigning each alternative a score on every one of these criteria. That way, we can see where each alternative stands, and the strength and weaknesses of each tool can be expressed more explicitly and precisely. A specific weight can then be assigned to each criterion, so the final weighted score can be computed. The alternative with the highest weighted score is considered to be the best.

Evaluation of Decision Tools - Evaluation Criteria

After a brainstorming session, followed by careful discussion, we came up with the following evaluation criteria.

1. Applet Type: We are dealing with two types of tools, Excel-based and Online. Excel-based tools require the user to be familiar with the program, and have minimal skill in inputting the data, since none of the Excel tools run macros for that. Because of that, Excel-based tools have value of 1, while Internet-based tools have value of 2 on this criterion.
2. Ease of use: It is important to know how user-friendly the tool is and how easy it is to get it to do what you need it to do. We've chosen a 0 to 5 range for this criterion, with "5" meaning "very easy" and 0 meaning "very hard/next to impossible".
3. Data storage: Whether or not the tool can store data or not is important for somebody who is planning a long-term project involving tool use. When you're dealing with the

tool for a long time, it can become irritating to input the same data every time you run the tool. This is a no/yes type criteria, so the range here is 0 or 1.

4. Qualitative data inputs: How many qualitative inputs does the tools take to perform calculations? Qualitative data may include your location, type of equipment or anything else, which cannot be quantified. Here we count the number of inputs needed and value of “10” really means “10 or more”. The more inputs the better the tool.
5. Quantitative data inputs: Here we count the numbers you need to input into the tool. The value of “10” really means “10 or more”. Again, more inputs warrant a better evaluation.
6. Cost analysis: The measure covers the analysis associated with different financial matters, such as installation costs, savings, taxes, etc. The scale here is 0 to 3, with 0 meaning “none at all” and 3 meaning “very explicit”.
7. Feasibility Analysis: This measure addresses how well the tool takes numerical data and develops feasibility ranges. The scale here is 0 to 3, with 0 meaning “none at all” and 3 meaning “very explicit”.
8. Environmental Analysis: The measure addresses how well the tool calculates an environmental impact of renewable energy initiative. This can include greenhouse effect or wildlife impact. The scale here is 0 to 3, with 0 meaning “none at all” and 3 meaning “very explicit”.
9. Qualitative data outputs: how many qualitative outputs does the tools give after performing calculations. Here we count the number of inputs needed and value of “10” really means “10 or more”.

10. Quantitative data outputs – how many quantitative outputs does the tools give after performing calculations. Here we count the number of inputs needed and value of "10" really means "10 or more"

Table # 5: Initial Scoring Model

Evaluation #	Evaluation Criteria	Range	A	B	C	D	E
1	Applet Type	Internet or Excel	I	I	I	E	E
2	Ease of Use	0-5, 5 is Preferred	2	5	3	3	4
3	Data Storage	Yes or No	No	No	No	Yes	Yes
4	Qualitative Data Inputs	0-10, 10 meaning, 10 or More	0	2	3	0	2
5	Quantitative Data Inputs	0-10, 10 meaning, 10 or More	0	5	1	10+	10+
6	Cost Analysis	None, Avg, Above Avg, Excellent	N	A	AA	E	E
7	Feasibility Analysis	None, Avg, Above Avg, Excellent	A	N	AA	A	E
8	Environmental Analysis	None, Avg, Above Avg, Excellent	A	N	A	N	AA
9	Qualitative Data Outputs	0-10, 10 meaning, 10 or More	2	0	1	0	2
10	Quantitative Data Outputs	0-10, 10 meaning, 10 or More	0	3	10+	6	10+

Table#6: Initial Scoring Model – Quantified

Evaluation #	Evaluation Criteria	Range	A	B	C	D	E
1	Applet Type	Excel (1) or Internet (2)	2	2	2	1	1
2	Ease of Use	0-5, 5 is Preferred	2	5	3	3	4
3	Data Storage	0 or 1	0	0	0	1	1
4	Qualitative Data Inputs	0-10, 10 meaning, 10 or More	0	2	3	0	2
5	Quantitative Data Inputs	0-10, 10 meaning, 10 or More	0	5	1	10	10
6	Cost Analysis	0-3	0	1	2	3	3
7	Feasibility Analysis	0-3	1	0	2	1	3
8	Environmental Analysis	0-3	1	0	1	0	2
9	Qualitative Data Outputs	0-10, 10 meaning, 10 or More	2	0	1	0	2
10	Quantitative Data Outputs	0-10, 10 meaning, 10 or More	0	3	10	6	10

Table#7: Legend

Tool ID	Tool
A	Small Wind Tool Box
B	PV Watts
C	My Solar Estimator
D	Simple Financial Model
E	Wind Energy Project

To help the user in deciding on which tool is best to use in a specific situation, we came up with this weighted scoring model for the evaluation criteria. It is an Excel-based program, which allows user to decide what is important and what isn't. The user assigns specific weights to each criterion, in accordance to user's needs and situation at hand. The total number of weight points has to be equal 100. Then the program multiplies those user-assigned weight points by the respective tool's scores (which are pre-set according to our Quantified Scoring Model on the previous page) and the results are all added together to get the final score for each tool. The tool with the highest score is said to be the best, but one can also see where the rest of them stand.

Table#8: User weighted scoring model 1

Evaluation #	Evaluation Criteria	Range	A	B	C	D	E
1	Applet Type	Excel (1) or Internet (2)	2	2	2	1	1
2	Ease of Use	0-5	2	5	3	3	4
3	Data Storage	0-5	0	0	0	5	5
4	Qualitative Data Inputs	0-5	0	1	2	0	1
5	Quantitative Data Inputs	0-5	0	3	0	5	5
6	Cost Analysis	0-5	0	2	4	5	5
7	Feasibility Analysis	0-5	2	0	4	2	5
8	Environmental Analysis	0-5	2	0	2	0	4
9	Qualitative Data Outputs	0-5	1	0	0	0	1
10	Quantitative Data Outputs	0-5	0	2	5	3	5

Weight	Criterion	Weight Description
10	Applet Type	Advantage of Internet-based tools over Excel-based ones?
10	Ease of Use	How important is the ease of use to you?
10	Data Storage	How important is the data torage to you?
10	Qualitative Data Inputs	How important is the number of Qualitative Data inputs to you?
10	Quantitative Data Inputs	How important is the number of Quantitative Data inputs to you?
10	Cost Analysis	How important is cost analysis to you?
10	Feasibility Analysis	How important is the feasibility analysis to you?
10	Environmental Analysis	How important is the enviromental analysis to you?
10	Qualitative Data Outputs	How important is the number of Qualitative Data outputs to you?
10	Quantitative Data Outputs	How important is the number of Qualitative Data outputs to you?
0	Points Remaining	
You have the proper results now		
Red values are set, do not change them		
Green values are inputs change them		

Tool ID	Tool	Weighted points
A	Small Wind Tool Box	90
B	PV Watts	150
C	My Solar Estimator	220
D	Simple Financial Model	240
E	Wind Energy Project	360

In the example above all criteria have the same weight, but this is only a pre-set. User may change those values in any way desired, and the results will change accordingly.

Table#8: User weighted scoring model 2

Criterion	Weight	
Applet Type	15	How much advantage do you want to give to Internet-based tools over Excel-based ones?
Ease of Use	2	How important is the ease of use to you?
Data Storage	20	How important is the data torage to you?
Qualitative Data Inputs	5	How important is the number of Qualitative Data inputs to you?
Quantitative Data Inputs	5	How important is the number of Quantitative Data inputs to you?
Cost Analysis	5	How important is cost analysis to you?
Feasibility Analysis	13	How important is the feasibility analysis to you?
Environmental Analysis	18	How important is the enviromental analysis to you?
Qualitative Data Outputs	7	How important is the number of Qualitative Data outputs to you?
Quantitative Data Outputs	10	How important is the number of Qualitative Data outputs to you?
Spare points	0	
You have the proper results now		
RESULTS		
Tool ID	Tool	Weighted points
A	Small Wind Tool Box	79
B	PV Watts	110
C	My Solar Estimator	217
D	Simple Financial Model	179
E	Wind Energy Project	307

Both Table#7 and Table#8 are in the report as an example. We leave the distribution of weights to the user, since a great number of different situations and personal demands make it impossible to say that one tool is definitely better than all the others.

Chapter Six

Conclusions

In general, Internet based programs were simpler in nature and easier to use. They don't require as many inputs as compared to excel based programs. In addition, Internet-based tools require more general information, such as location data, while Excel-based tools may require more specific inputs. Excel based tools provide a much more thorough analysis of the situation, and contain larger databases. They require and provide more information, when in use. The greatest advantage of the Excel-based tools over Internet-based tools is that Excel allows user to store data, and there is no need to run the same calculations over again.

We have decided to present the data by showing which tool type outperforms the other for each evaluation criteria. In terms of ease of use, internet based applets had an average score of 3.3 while excel based programs had an average of 3.5. There were three internet based programs evaluated versus two excel based programs, which explains why excel based programs have a higher ease of use rating that the internet based tools. Internet based applets did not offer data storage whereas excel based programs offer storage. Internet based programs are preferred as they take less inputs than excel based programs making them able to provide a general analysis rapidly. Excel based programs perform extensive analysis of cost, environmental, and feasibility data which is related to the high number of inputs as compared to internet based programs. In terms of outputs excel based programs have an advantage over internet programs with an average of 4.5 where as internet based programs have an average of 4.0.

Our final recommendation is that excel based programs are preferred to internet based programs, unless the user is limited in the amount of data available and would be satisfied with a quick but potentially shallow answer.

Future Considerations

Looking back on the project as a whole, if we were provided with non-freeware tools we may have been able to generate a more complete analysis. In comparing internet based applets to excel based applets, we did not explore other variations of applets based in other programs. We limited our scope to focus on more widely used program types that are available to Windows based computer users. In consideration of this limitation we would need to expand our scope to include more program types. In addition we evaluated three internet based programs and two excel based programs if this experiment were done again an equal number of tools for each type would be evaluated to generate a better comparison. Time was a limiting factor also in our investigation, as we were able to gain limited knowledge in the fields of distributed generation and renewable energy systems. Our limited knowledge, based on our research was adequate to satisfy our project goals,; however, we could have achieved more if given the opportunity to thoroughly study our central topics.

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