Cornell University

Department of Electrical and Computer Engineering

Optimization of renewable sources of energy use for a farmland application at Ridgecrest, NY

A Design Project Report

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By

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Abstract

Master of Electrical and Computer Engineering Program
Cornell University
Design Project Report

Project Title: Optimization of renewable sources of energy use for a farmland application at Ridgecrest, NY

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Renewable sources of energy can be extensively used to meet the energy requirements of industrial, agricultural and commercial applications across the nation. This project is aimed at achieving a cost effective solution to meet a farm's energy needs by optimizing use of renewable sources of energy. Besides going green, the other objectives for this project were to reduce carbon footprint and to cut huge electricity bills. These objectives were achieved by creating a hybrid solution, which provided increased flexibility and captured benefits from tax and other subsidies. Ridgecrest Farm is a mid-sized dairy farm located in Genoa, New York. The farm currently has 1650 cows, and will soon expand to 2000. The devised system is capable of utilizing wind and solar energy, both with utmost efficiency using photovoltaic and wind turbine, respectively. The project was designed using Renewable Energy Project Analysis Software, available from the research centre of Natural Resources Canada. Renewable-energy and Energy-efficient Technologies (RET) gives the flexibility to model different case scenarios between various combinations of solar photovoltaic and wind turbine from the available database and find the most efficient solution. A comparative analysis of several photovoltaic panels and wind turbines was conducted in the process.

The approach adopted to carry out the analysis was a 5-step method. First, the conditions of the site were chosen, followed by developing an energy model which accounted for the kind of project being designed (solar/wind/hybrid), followed by selecting the contribution from each category of source of energy. After choosing the project configuration, cost analysis was carried out using information from different model types and the final step of financial analysis was carried out using details of the plant such as cost, lifetime and the incentives applicable that calculated the resulting payback period for the project.

After careful consideration, the most optimal solution was achieved by running multiple iterations using different case scenarios and eventually a pay back period of around 5 years and equity payback of less than 5 years has been achieved.

Report Approved by

Project Advisor: ____________________________ Date: _____________

Executive Summary

Renewable sources of energy can be extensively used to meet the energy requirements of industrial, agricultural and commercial applications across the nation. According to many renewable energy experts, a small "hybrid" electric system that combines wind and solar (photovoltaic) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. [1]

The main objectives of this project were to:

- Meet the energy requirements of the dairy farm through renewable sources of energy.
- Cut electricity costs
- Reduce carbon foot print

Ridgecrest Farm is a mid-sized dairy farm located in Genoa, New York. The farm currently has 1650 cows, and will soon expand to 2000. The devised system is capable of utilizing wind and solar energy, both with utmost efficiency using photovoltaic and wind turbine, respectively. The project was designed using Renewable Energy Project Analysis Software, available from the research centre of Natural Resources Canada. Renewable-energy and Energy-efficient Technologies (RET) gives the flexibility to model different case scenarios between various combinations of solar photovoltaic and wind turbine from the available database and find the most efficient solution. A comparative analysis of several photovoltaic panels and wind turbines was conducted in the process.

The approach adopted to carry out the analysis was a 5-step method. First, the conditions of the site were chosen, followed by developing an energy model which accounted for the kind of project being designed (solar/wind/hybrid), followed by selecting the contribution from each category of source of energy. After choosing the project configuration, cost analysis was carried out using information from different model types and the final step of financial analysis was carried out using details of the plant such as cost, lifetime and the incentives applicable that calculated the resulting payback period for the project.

After careful consideration, the most optimal solution was achieved by running multiple iterations using different case scenarios and eventually a pay back period of around 5 years and equity payback of less than 5 years has been achieved. This was generated considering the different models with improved efficiency and incentives applicable to it. Looking at the overall picture, it seems to be a very plausible solution to invest in green technology.

Table of Contents Page No.

1. INTRODUCTION

1.1 Problem Definition and Objectives

Renewable sources of energy can be extensively used to meet the energy requirements of industrial, agricultural and commercial applications across the nation. Some of the commonly used renewable energy systems utilize biomass, hydropower, solar energy, tidal power, wind energy and anaerobic digesters, etc. In this case, the objective is to design a hybrid system using solar photovoltaic and wind turbine such that the best optimal solution can be achieved using both of them simultaneously. At the same time, making sure we achieve a cost effective solution for a farmland application upstate NY with the lowest payback period.

There are several reasons behind carrying out this project. The key reasons of all being able to bring about a difference in the world we live. This project is aimed at meeting the energy requirements of a dairy farm through renewable sources of energy. Besides cutting down huge electricity costs, it also helps in reducing carbon foot print and with the possibility of net metering, also allows us to return excessively produced energy back to the grid

Ridgecrest Farm is a mid-sized dairy farm located in Genoa, New York. The farm currently has 1650 cows, and will soon expand to 2000. This project is aimed at achieving a cost effective solution by which the farm can meet all its energy needs with some form of renewable energy. The devised system must be capable of utilizing wind and solar power with the utmost efficiency while retaining a payback period of less than five years. According to NYSEC electricity bills, Ridgecrest Dairy is able to run their current operations on approximately 820,000 KWh/yr.

The model is being designed using the RET Screen Clean Energy Project Analysis Software, available from the research centre of Natural Resources Canada. [2] Renewable-energy and Energy-efficient Technologies (RET) gives the flexibility to model different case scenarios and study the most efficient of them, which can finally be implemented. A comparative analysis of several PV Panels and wind turbines was taken into consideration. This project is aimed at developing different case scenarios using different combinations of both solar (PV) and wind turbine options available to capture maximum benefits.

1.2 Why renewable sources of energy?

We have all been hearing the buzzwords such as sustainability, renewable/alternate forms of energy, green technologies, etc but how many of us have really given them a second thought. This project brings to light the unrealized advantages of using these forms of energy. Before I go any further, let me define what it means by renewable sources of energy. As defined by Public Interest Energy Research (PIER), Renewable resources mean “Naturally replenishable, but flow-limited energy resources which are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future they could also include the use of ocean thermal, wave, and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid-connected generation, and demand-reduction (energy efficiency) technologies.“ [3]

In the words of President Barrack Obama “We know the country that harnesses the power of clean, renewable energy will lead the 21st century.” [4] "The nation that leads the world in creating new energy sources will be the nation that leads the 21st century global economy. America can be that nation."[5]

It is no doubt that after hearing people from all over the world who have shared a common interest in bringing about a change to this world; it is high time that we must realize resource allocation to answer the ever-growing needs. Renewable energy accounted for more than 10 percent of the domestically produced energy used in the United States in the first half of 2008. [6]

1.2.1 Why PV?

PV that stands for Photovoltaic or Photovoltaic Panel is a packaged interconnected assembly of photovoltaic cells, also known as solar cells. [7] PV Panels offer high reliability and need little maintenance. [8] It costs little to build and operate. PV cells use the energy from sunlight to produce electricity in which case the fuel is free. With no moving parts, the cells require little upkeep. Without doubt, it offers environmental benefits and has virtually no environmental impact. With zero emissions, it is pollution-free in operation. Because they burn no fuel and have no moving parts, PV systems are clean and silent. With flexibility in terms of size and applications being the key distinguisher, A PV system can be constructed to any size based on energy requirements. It's produced domestically, strengthening our economy and reducing our trade deficit. It helps energy service providers manage uncertainty and mitigate risk. [8] PV systems are usually placed close to where the electricity is used, requiring much shorter power lines than if power is brought in from the utility grid. In addition, using PV eliminates the need for a step-down transformer from the utility line. Less wiring means lower costs, shorter construction time, and reduced permitting paperwork, particularly in urban areas. Though they have a high initial cost of installation, in the long run, it works out cheap. [9]

1.2.2 Why Wind?

The potential for wind energy is immense, and experts suggest wind power can supply up to 20% of U.S. and world electricity. [10] There is a huge untapped wind energy, which is out there and needs to be harnessed. This project is taking place in upstate NY where the speed of wind is determined using AWS True wind Navigator. [11] It is found to be around 6.51m/s, which can be easily harnessed, to power the farm needs.

There are other advantages of using wind energy besides just being free fuel. Wind energy revitalizes rural economies and can add a new source of property taxes in rural areas that otherwise have a hard time attracting new industry. Each 100 MW of wind development in southwest Minnesota has generated about $1 million per year in property tax revenue and about $250,000 per year in direct lease payments to landowners. [10]

Worldwide, over 86 percent of wind generation capacity is primarily split between Europe (72 percent) and the United States (14 percent). A 100 MW wind farm will, over the course of 20 years, displace the need for nearly 1 million tons of coal, or nearly 600 billion cubic meters of natural gas. [12]

1.2.3 Why hybrid?

There are several reasons why a hybrid system is better than a stand alone solar or wind energy system. The rational behind this can be explained by the small extract, which was obtained from Small “Hybrid” Solar, and Wind Electric Systems article. [1]

“According to many renewable energy experts, a small "hybrid" electric system that combines wind and solar (photovoltaic) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it.”

Not only are the benefits of installing two different kinds of system helpful from a diversification perspective, but tax and other benefits that come along as subsidies. Since there is a separate bracket of benefits for operating below a certain level, we must judicioulsy decide so that we do not miss capturing those effects. For instance, the NYSERDA offers benefits to the tune of $4/W upto 25kW and 3$/W from 25-50kW photovoltaics. This itself is a very phenomenal incentive compensation ($25000x4=$100,000). [17,18]These therefore allow us to follow within different benefit limits to obtain as much funding as possible from government and other resources.Also, one can run photovoltaics during summer when the sun is shining bright and use the windmill more efficiently in the winter. There are almost 25 per cent more air molecules in a cubic metre of the cold air than in a cubic metre of the warm air. [13]

For all the above reasons, it is most advantageous to use a hybrid system.

2. DESIGN OVERVIEW

Essentially, it needs to be figured out as to what is the best implementation by which we can achieve the electricity needs of the farm. The other issues that need to be considered in this case are to study the individual parameters carefully in both the energy power systems as described below.

2.1 Photovoltaic

Some of the key factors that determine the installation are as follows:

2.1.1 Available space

Since designing the PV Solar Cell will require the exact dimensions of the solar panel (modules), it is therefore essential to know the amount of space available so that the calculations can be made accordingly.

2.1.2 Optimum tilt angle

This is one of the most crucial determining factors in the case of installing a solar cell. Since, the sunlight falls at a particular angle during the day, it is very important to study the optimum tilt angle so that we can achieve maximum efficiency that can be cranked out of the system.

2.1.3 Sun hours (kWhr/m^2/day)

The number of sun hours given in the parentheses as kilowatt hour per area per day will provide me the parameter to design the model and calculate it's efficiency.

2.1.4 Wiring Size

The amount of power a wire can safely carry is related to how hot it can safely get. Wires have resistance and as power flows through them, that resistance causes heat to build up. The more power you put through a wire, the hotter it gets. Insulation breaks down when it gets too hot, and at some point it will melt away; leaving the wire exposed to whatever is around it – possibly causing a fire. Once the exact load is known, the size of the wire can be accordingly decided. [14]

2.2 Wind Turbines

Some of the important factors that determine the installation of a wind turbine are discussed below. Since these are huge investments, due diligence needs to be done before making any purchases.

2.2.1 Wind speed

One of the most important factors while installing a wind turbine is to estimate the wind speed. Although wind speed fluctuates at every site, it is important to find a site where the average wind speed is close to the rated wind speed for the selected turbine. [24]

2.2.2 Height

The height of the wind turbine determines which model to be used as the wind power at different height varies and brings about a lot of difference. As we go higher and higher the wind speed increases. Another consideration to be made while determining height is the turbulence avoidance. Turbulence will decrease the effectiveness of the turbine resulting in decreased electricity generation and it will increase the wear and tear on the turbine resulting in increased maintenance. [24]

2.2.3 Wind Directionality

To define the characteristics for a wind turbine installation, it is imperative to know the wind directionality. The wind directionality would remain the same irrespective of which height the turbine was selected because in that small a range, the directionality does not change drastically. [15]

3. INCENTIVE PROGRAMS

One of the reasons going into renewable sources of energy is because the government offers subsidies to home owners and commercial property owners for installing systems using renewable sources of energy. In this case, benefits can be obtained from both solar and wind energy subsidies. There are a number of incetives available to agricultural businesses on both the state and federal level. Over the years, incentives and mandates for renewable energy have been used to advance different energy policies, such as ensuring energy security or promoting environmentally benign energy sources. Renewable energy has beneficial attributes, such as low emissions and replenishable energy supply, that are not fully reflected in the market price. Accordingly, governments have used a variety of programs to promote renewable energy resources, technologies, and renewable-based transportation fuels. [16]

The different Incentive programs are discussed below.

3.1 Solar Energy Incentive Programs

Below is an overview of the New York State Energy Research and Development Authority (NYSERDA) solar electric incentive program, as well as the U.S. Department of Agriculture (USDA) Rural energy for America Program (REAP) incentive and the federal Business Energy Tax Credit. These incentives could potentially make ahuge difference to the initial investment.

3.1.1 NYSERDA Solar Electric Incentive Program

The NYSERDA Electricity Incentive Program provides cash incentives for the installation of new solar electric or PV systems. The New York State Renewable Portflolio Standard has allocated approximately $13.8M in incentives through 2009 as well as an additional $20.6M in October 2008. Incentivesusually cover about 40-45% of the installed cost of a PV Sytem ($4/W upto 25kW and 3$/W from 25-50kW). [17,18]

3.1.2 Business Energy Tax Credit (DSIRE) Program

At the federal level, this one provides incentives to the tune of 30% of the total expenditure. These tax credits were expanded by eight years by the Energy Improvement and Extension Act of 2008, enacted in October 2008. Credits are available for eligible systems placed on or before December 31, 2016.[25]

3.1.3 USDA Rural Energy for America Program (REAP)

The REAP Guaranteed Loan Program encourages the commercial financing of renewable energy projects. These grants are limited to 25% of a proposed project's cost, and a loan guarantee may not exceed $25 million. The combined amount of a grant and loan guarantee may not exceed 75% of the project’s cost. Besides offering higher loan amount and lower interest rates, this also provides longer repayment terms that can assist businesses that may not qualify for conventional lender financing, an easy way to investment. [17][19]

3.2 Wind Energy Incentive Programs

These incentives will most directly affect the farm's decision to invest in wind energy as they substantially reduce the cost of a PV system.

3.2.1 Wind Incentive Program

Specific incentives for wind technology deployment and infrastructure development by the NYSERDA in the state are at least $2.5 million. The good news is that costumers, including Ridgecrest Farm, who pay the System Benefits Charge, are eligible for these incentives as a wide variety of electricity suppliers are included.

Incentives are based on a percentage of the installed cost, ranging from 50% of costs for systems of 500 Watts to 10,000W (10kW), to 15% for systems larger than 80 kW. Larger incentives of up to 70% of costs are available for commercial farms, and for school applications where wind energy study is incorporated into its curriculum. [20]

3.2.2 NYSERDA Renewables Research and Development Program

The New York State Energy Research and Development Authority has a research program which is offered typically on annual basis with annual funds averaging $2 million. So far, Some 400 NYSERDA research projects help the State's businesses and municipalities with their energy and environmental problems. Being wind one of the larger energy recipients of this program, and having funds available to commercial, industrial, residential and utilities sectors, this is a very important incentive in this case like in Photovoltaics. The program could fund up to 50% of the Ridgecrest wind farm costs as long as the expenditures rank between $10,000 and $200,000. [20]

3.2.3 Small Wind Systems Tax Credit

Under present law, a federal-level investment tax credit (ITC) is available to help consumers purchase small wind turbines for home, farm, or business use. Owners of small wind systems with 100 kilowatts (kW) of capacity or less can receive a credit for 30% of the total installed cost of the system. [20]

3.3 Renewable Portfolio Standard

The RPS seeks to ensure that at least 25% of NY's electric use is from renewable sources by the end of 2013. Initially, the NY RPS will encourage the development of renewable resources primarily through a centrally administered, incentive-based procurement mechanism that will be managed by the New York State Energy Research and Development Authority (NYSERDA). An Order issued and effective September 24, 2004 by the New York Public Service Commission (PSC) enacted a renewable portfolio standard (RPS). The PSC estimates that RPS target will require an additional 3,700 MW of renewable resource generation capacity. The RPS program identifies two tiers of eligible resources, a Main Tier and a Customer-Sited Tier. Potentially eligible resources for the Customer-Sited Tier include fuel cells, photovoltaic, and certain wind resources. The RPS program for customer-sited resources will most likely replace NYSERDA's exiting incentive programs for solar photovoltaic and small wind energy system and be managed in a similar manner. [20]

3.4 Solar and Wind Energy Systems Exemption

Real property that contains a solar, wind, or farm waste energy system approved by the State Energy Research and Development Authority is exempt from taxation for a period of 15 years to the extent of any increase in assessed value due to the system. Such property is liable for special ad valorem levies and special assessments. The exemption as reenacted in 1990 is subject to local option. [22]

3.5 Net Metering

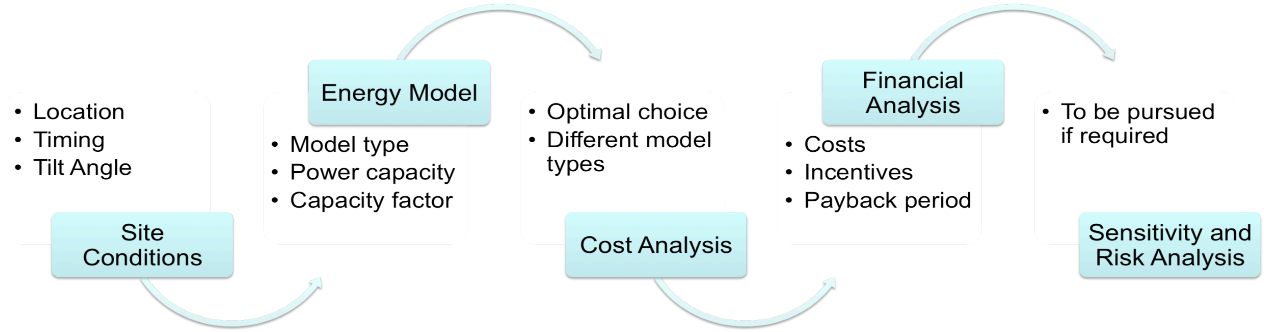
Net metering allows the user to actually sell the extra credits over and above their own requirements, back to the grid to make future cash flows. When New York enacted its net metering law, Public Service Law Section 66-j, in 1997, it included only facilities powered by solar energy. On September 14, 2004, the Governor signed a bill which expanded New York's net metering law to include residential wind turbines of 25 kW or smaller and farm-based wind turbines of 125 kW or smaller. At the end of each month, net excess generation for wind turbines of 10 kW or less is credited to the next month's bill at the retail rate. As a result of this law, the utilities will prepare tariffs that will be submitted to the New York State Department of Public Service (DPS) for approval. [20] Net metering is available on a first-come, first-served basis to customers of the state's major investor-owned utilities, subject to technology, system size and aggregate capacity limitations. [23]

4. APPROACH

4.1 Model

The goal of this design project was to develop a hybrid system which would be most beneficial to the Ridgecrest Dairy farm. In order to achieve this, I ran numerous iterations in RET Screen software using various models to acheieve the most optimal solution for our case.

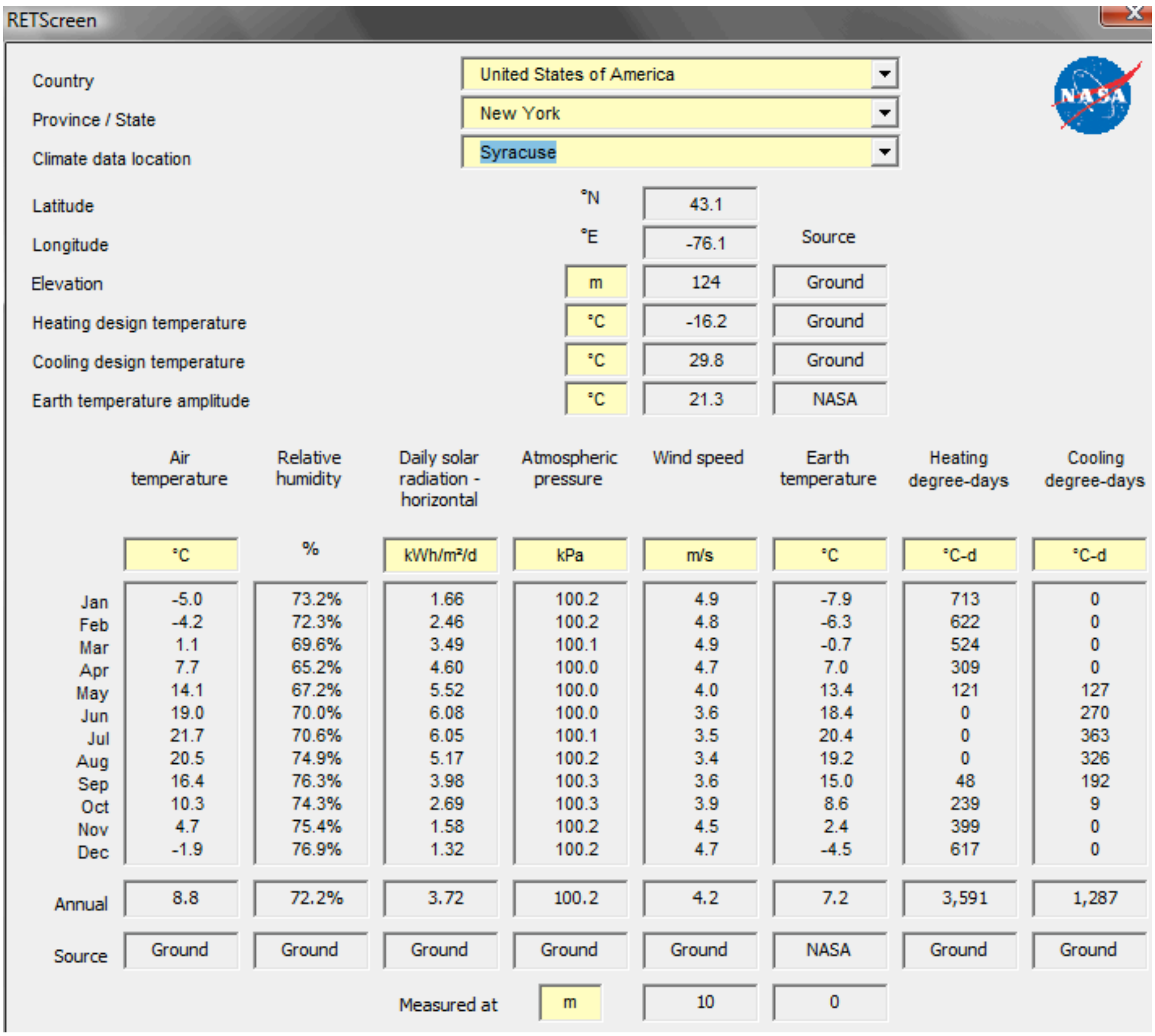
According to many renewable energy experts, a small "hybrid" electric system that combines wind and solar (photovoltaic) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. [1] The methodology adopted is explained as below:



4.2 Design steps

Step 1:

First and foremost, the site conditions were found out to enable the site settings in the software. RET Screen Model allows the user to choose the site settings where the project is taking place. In our case, the data has been taken from Syracuse since it is the closest data available to our site. It also accoutns for tilt angle that is used for photovoltaic. The next step is to manually calculate the electrical load. In this step, we would essentially examine the uses of energy in the farmland.



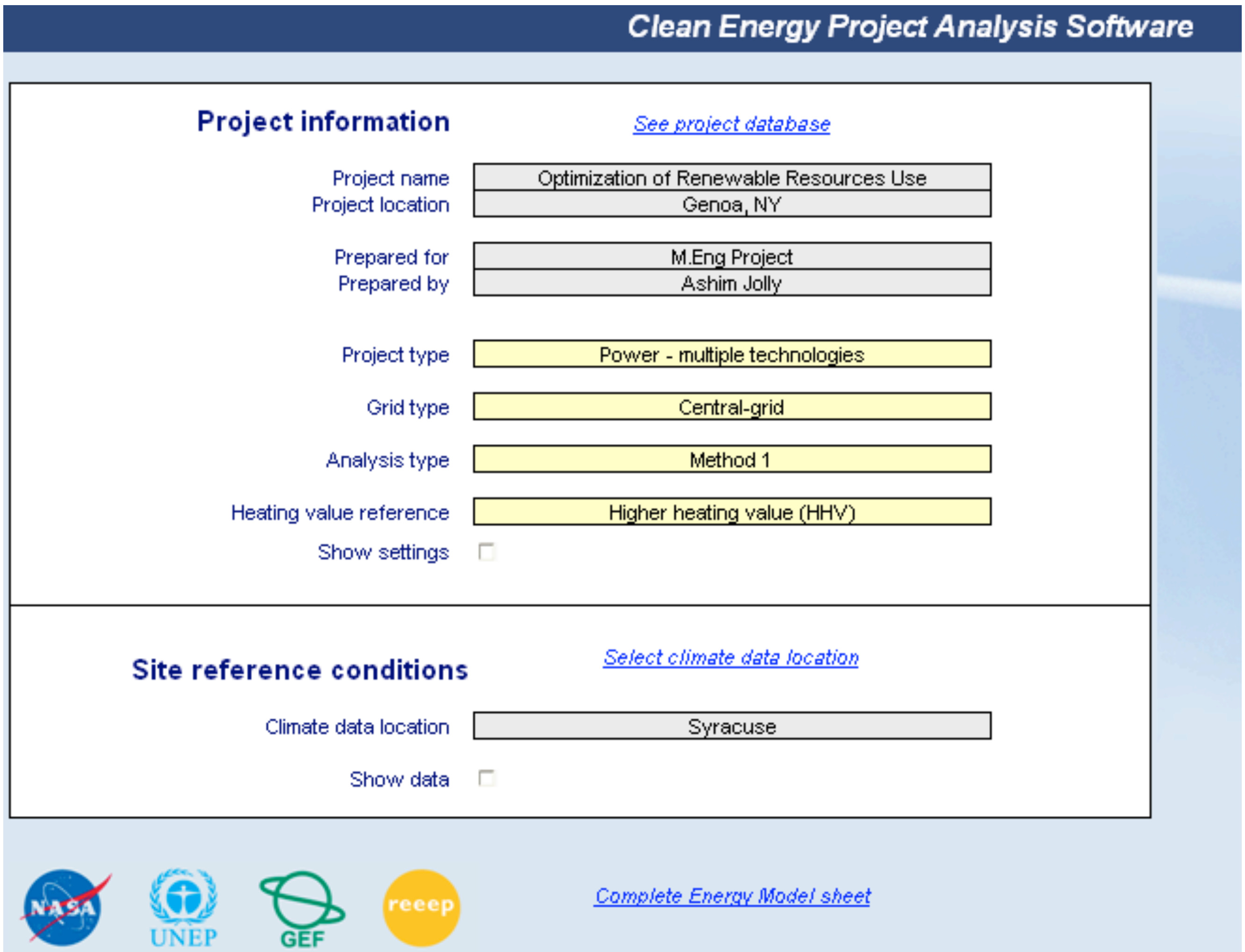
RETScreen

Country		United States of America	
Province / State		New York	
Climate data location		Syracuse	
Latitude	°N	43.1	Source
Longitude	°E	-76.1	
Elevation	m	124	Ground
Heating design temperature	°C	-16.2	Ground
Cooling design temperature	°C	29.8	Ground
Earth temperature amplitude	°C	21.3	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	-5.0	73.2%	1.66	100.2	4.9	-7.9	713	0
Feb	-4.2	72.3%	2.46	100.2	4.8	-6.3	622	0
Mar	1.1	69.6%	3.49	100.1	4.9	-0.7	524	0
Apr	7.7	65.2%	4.60	100.0	4.7	7.0	309	0
May	14.1	67.2%	5.52	100.0	4.0	13.4	121	127
Jun	19.0	70.0%	6.08	100.0	3.6	18.4	0	270
Jul	21.7	70.6%	6.05	100.1	3.5	20.4	0	363
Aug	20.5	74.9%	5.17	100.2	3.4	19.2	0	326
Sep	16.4	76.3%	3.98	100.3	3.6	15.0	48	192
Oct	10.3	74.3%	2.69	100.3	3.9	8.6	239	9
Nov	4.7	75.4%	1.58	100.2	4.5	2.4	399	0
Dec	-1.9	76.9%	1.32	100.2	4.7	-4.5	617	0
Annual	8.8	72.2%	3.72	100.2	4.2	7.2	3,591	1,287
Source	Ground	Ground	Ground	Ground	Ground	NASA	Ground	Ground
Measured at				m	10	0		

Step 2:

In this step, we defined values for various systems from the database available to us. We know that the rated output wattage of the panel is the amount of watts the panel will create in one hour of direct sun. The next step is to study the total electrical requirement of the farmland and calculate the size of the farmland PV System. Capacity factor also needs to be regarded in the calculation. Capacity factor is one element in measuring the productivity of a wind turbine or any other power production facility. It compares the plant's actual production over a given period of time with the amount of power the plant would have produced if it had run at full capacity for the same amount of time. [26] In order to estimate the size of the PV System we studied the exact requirement of electrical power in the farmland given all the resources are being utilized under optimum conditions. As different size PV panels will produce different amounts of power, we chose most appropriate sizes for the farmland.



Choosing the energy model.

According to the needs of the kind of model we are using, we must select the right project to run our analysis. RET Screen has predefined models to choose from. The list of available models can be found in appendix C(i) for Photovoltaic and C(ii) for Wind Turbines.

There are a variety of models to choose from the database. In this case, I have used the solar photovoltaic Sanyo mono Si-HIP195BA3 with capacity 390kW and the wind turbine has been chosen as Largey Wind turbine 18/80 with 80kW capacity.

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	◉	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	390.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-195BA3	2000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	512.5	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	80	
Manufacturer		Lagerwey Windturbine	
Model		LAGERWEY 18/80 - 52m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	210	

Step 3 and 4:

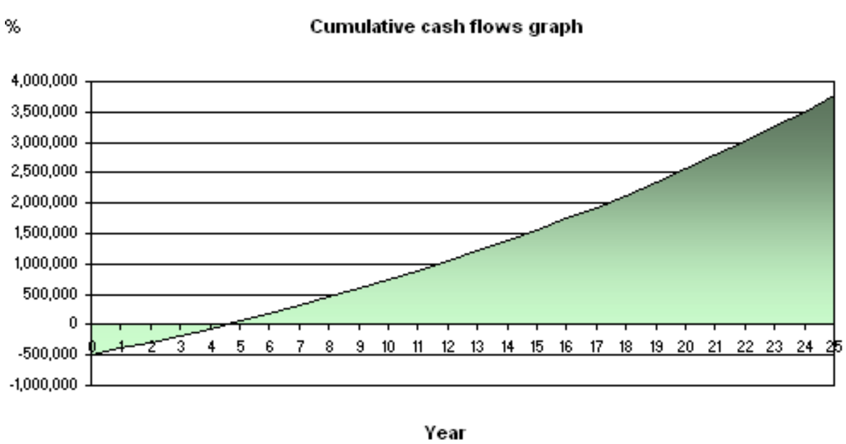
Cost Analysis, as the name suggests allows us to analyze the cost of the system based on various factors. In order ta anlayze the optimal choice, we need to calculate the costs incurred upfront and the operations and mainteneance cost.

This step helps us really determine what options to choose as we go along making our decision. This tool gives us the flexibility to add details about cost and Incentives that we have discussed before as it will determine the payback period. The graph is obtained after filling in those values that are obtained from different solar panel and wind turbine vendors.

Then, the Financial Analysis tool is used to determine the financial implications of using this particular model. As explained below, we use an inflation rate of 4%. The product life for photovoltaic is around 25 years. The initial investment is about $2,476,000 and incentives net total to $1,980,800(approximately). The annual cost of maintenance is around $37,5000. The annual savings determined is around $56,500.

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,476,000
Total initial costs	$	2,476,000
Incentives and grants	$	1,980,800
Annual costs and debt payments		
O&M (savings) costs	$	37,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	37,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	79,497
	$	56,500
Total annual savings and income	$	135,997
Financial viability		
Pre-tax IRR - assets	%	24.5%
Simple payback	yr	5.0
Equity payback	yr	4.5

The graph is obtained from the Cost Analysis. In our case, we have rounded up the figures to achieve the pay back period. The inflation rate has been taken as 4% (on an average), the lifetime of the panel is around 25 years yields a payback period of 5 years.



Pay back period = 5.0 years

Step5:

This step is used to find out the Risk and Sensitivity Analysis, which has not been conducted in this case. The reason behind this being that the model which is generated has already considered the various options available to us as an end user and we need not determine risk and sensitivity analysis for these individual cases.

The model has been iterated for multiple number of times and the optimal findings have been tabulated.

The best case example has just been discussed here. The other iteartions have been put in the appendix.

Table of the entire scenario with different iterations shown in appendix B.

Table No. 1

No.	Solar Type	Capacity per unit(kW)	Wind type	Capacity per unit (kW)	Energy (kW)	Payback Period
1	Centennial Solar 280	280	Entegrity Wind Sys 15	50x3	824,200	6.9 yrs
2	Sanyo mono-Si HIP205BA3	451 (2200x205W)	Atlantic Orient AOC 15/50	50	832,000	5.3 yrs
3	Shell mono-Si Ultra 85P	90.1 (1060x85W)	Wind Energy Solutions	250	845,300	6.4 yrs
4	Sanyo mono-Si HIP205BA3	451 (2200x205W)	Energie PGE 20/25	2x25	830,000	5.6 yrs
5	Shell ST40W	90 (2250x40W)	Wind Energy Solutions	250	838,800	6.3 yrs
6	Centennial Solar a-Si CS 90	90 (1000x90W)	Wind Energy Solutions	250	840,000	6.0 yrs
7	Centennial Solar 280	280	WES 18	80x2	878,500	6.4 yrs
8	Sanyo mono-Si HIP205BA3	451 (2200x205W)	Entegrity Wind Sys 15	50	830,500	5.7 yrs
9	Centennial Solar 280	280	Atlantic Orient	50x3	824,000	7.5 yrs

10	Kyocera poly-Si KC60	90 (1500x60W)	Wind Energy Solutions	250	838,800	5.8 yrs
11	Sanyo m-Si HIP205BA3	451 (2200x205W)	Bergey BWC Excel 36.6m	50	832,500	5.4 yrs
12	Centennial Solar 280	280	Lagerway 18/70	80x2	878,000	7.7 yrs
13	Sanyo m-Si HIP195BA3	390 (2000x195W)	Lagerway 18/80	80	822,000	5.0 yrs
14	Sanyo mono-Si HIP195BA3	390 (2000x195W)	Wind Energy Solutions WES 18	80	822,500	5.1 yrs
15	Sanyo mono-Si HIP195BA3	390 (2000x195W)	Vergnet	20x4	832,000	5.4 yrs

5. CONCLUSION

Why hybrid system is worth the investment?

Having looked at the different cases using different types of Solar panels and Wind turbines, we are able to model the best case wherein we have achieved a payback period around 5 years and equity payback of 4.5 years. Most of these systems come with a warranty of 20-25 years and therefore one need not worry about the lifetime value of the product.

Not only are we able to capture the advantages from subsidies and tax benefits, the farm will also avoid emissions of carbon dioxide which contribute to global warming. The farm can therefore call itself a more sustainable one.

Under the hybrid conditions assumption, we have been able to find out that the maximum payback period around 7 years and the lowest payback period less than 5 years. From table no. 1, we observe that the best combination is no. 13 with Sanyo mono Si-HIP195BA3 (capacity 390kW) and the wind turbine as Largey Wind turbine 18/80 (80kW capacity)with lowest payback period of 5 years or equity payback period of 4.5 years.

As we know, that the Ridgecrest farm is on a cusp of major change and they are bringing in another 350 cows, their electricity requirement is going to change considerably. However, since the farm is currently in the planning stage, this can very well serve as a direction to choosing the best option for the farm’s needs.

6. ACKNOWLEDGMENT

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Last but not the least, I express my heartfelt thanks to the department of Electrical and Computer Engineering which provided me the opportunity to work on this project.

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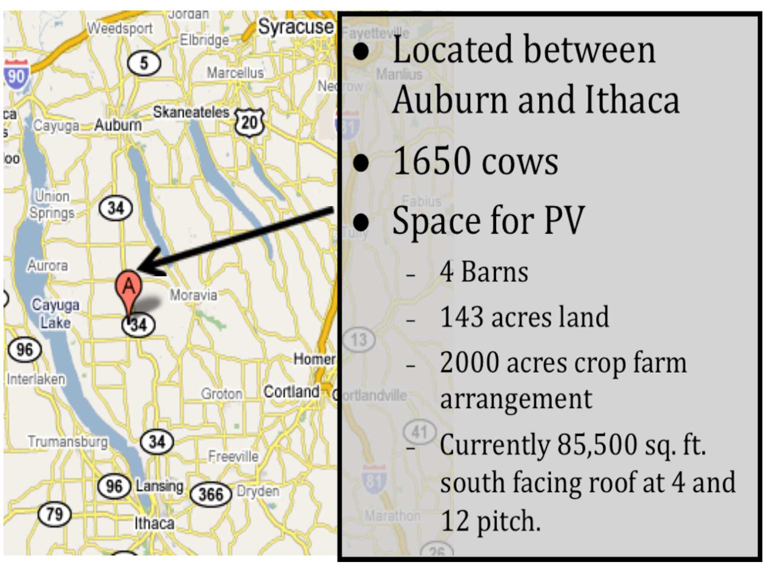
APPENDIX A : **Farm Overview**

Farm:

Farm map



APPENDIX B : **RET Screen Iterations for the 15 different case scenarios**

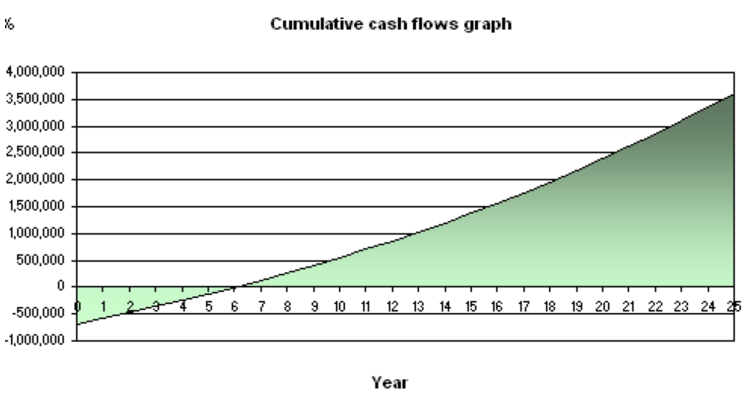
Iteration 1

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type		⦿ Method 1 / ○ Method 2	
Photovoltaic #1			
Power capacity	kW	280.00	
Manufacturer		Centennial Solar	
Model		poly-Si - CS280	1000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	367.9	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	150	
Manufacturer		Entegrity Wind Systems	
Model		EW15 - 25m	3 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	394	

Centennial Solar 280 and Entegrity Wind Sys 15

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,230,000
Total initial costs	$	2,230,000
Incentives and grants	$	1,540,500
Annual costs and debt payments		
O&M (savings) costs	$	54,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	54,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	88,406
	$	65,500
Total annual savings and income	$	153,906
Financial viability		
Pre-tax IRR - assets	%	18.4%
Simple payback	yr	6.9
Equity payback	yr	6.0

280kW and 150 kW, repectively



Pay back period = 6.9 yrs

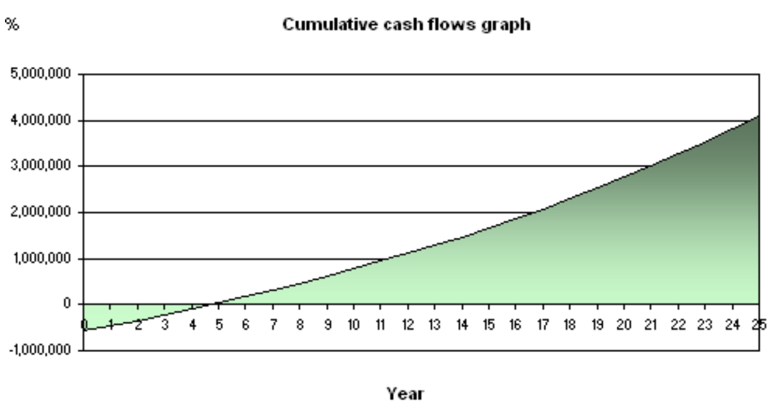
Iteration 2:

Proposed case power system

Base load power system			
Technology		Photovoltaic	
Analysis type		⦿ Method 1 / ○ Method 2	
Photovoltaic #1			
Power capacity	kW	451.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-205BA3	2200 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	592.6	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	50	
Manufacturer		Atlantic Orient	
Model		AOC 15/50 - 25m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	131	

Financial Analysis

Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,790,000
Total initial costs	$	2,790,000
Incentives and grants	$	2,218,500
Annual costs and debt payments		
O&M (savings) costs	$	28,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	28,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	84,710
	$	51,500
Total annual savings and income	$	136,210
Financial viability		
Pre-tax IRR - assets	%	23.3%
Simple payback	yr	5.3
Equity payback	yr	4.7

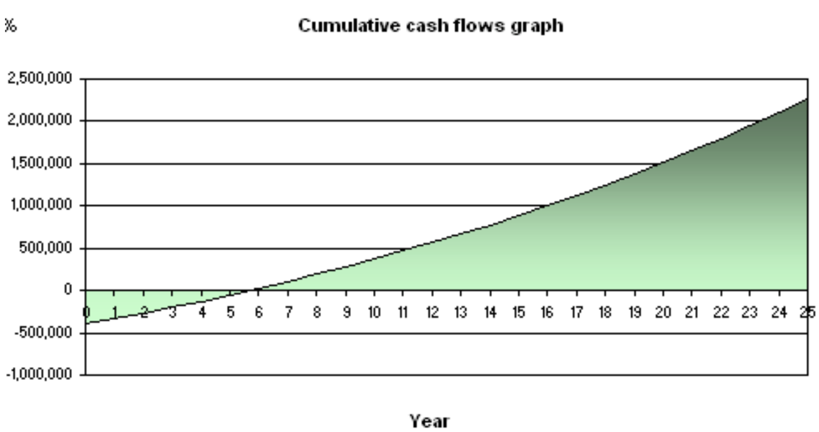


Pay back period = 5.3 yrs

Iteration 3:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦿	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	90.10	
Manufacturer		Shell	
Model		mono-Si - Ultra 85-P	1060 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	118.4	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	250	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 30 - 30m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	657	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	1,000,000
Total initial costs	$	1,000,000
Incentives and grants	$	602,500
Annual costs and debt payments		
O&M (savings) costs	$	93,000
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	93,000
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	89,170
	$	65,500
Total annual savings and income	$	154,670
Financial viability		
Pre-tax IRR - assets	%	19.6%
Simple payback	yr	6.4
Equity payback	yr	5.6

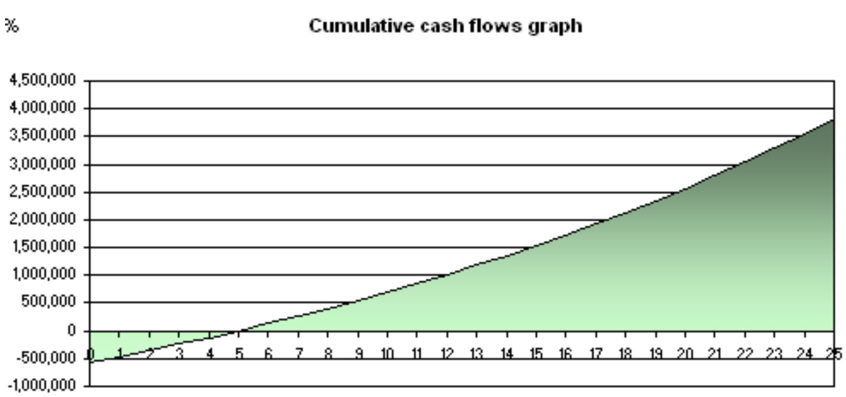


Pay back period= 6.4 yrs

Iteration 4:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⊗	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	451.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-205BA3	2200 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	592.6	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	50	
Manufacturer		Energie PGE	
Model		PGE 20/25 - 37m	2 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	131	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,784,500
Total initial costs	$	2,784,500
Incentives and grants	$	2,216,000
Annual costs and debt payments		
O&M (savings) costs	$	35,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	35,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	79,642
	$	57,000
Total annual savings and income	$	136,642
Financial viability		
Pre-tax IRR - assets	%	22.2%
Simple payback	yr	5.6
Equity payback	yr	5.0

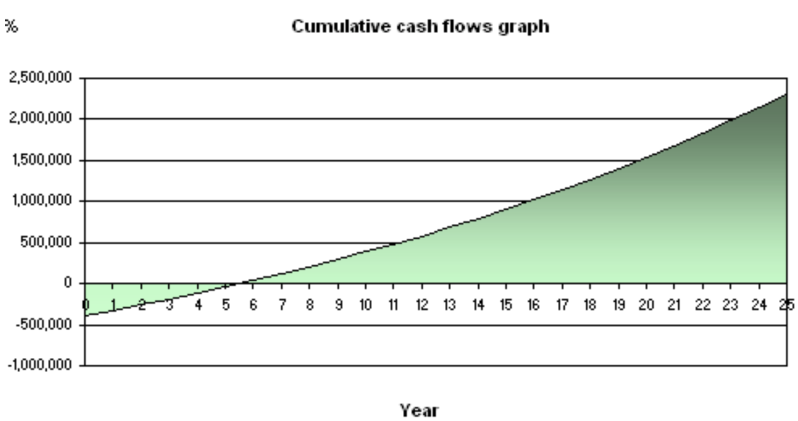


Pay back period = 5.6 yrs

Iteration 5:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦻	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	90.00	
Manufacturer		Shell	
Model		CIS - ST40W	2250 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	118.3	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	250	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 30 - 30m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	657	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	990,000
Total initial costs	$	990,000
Incentives and grants	$	599,500
Annual costs and debt payments		
O&M (savings) costs	$	91,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	91,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	85,279
	$	68,500
Total annual savings and income	$	153,779
Financial viability		
Pre-tax IRR - assets	%	20.1%
Simple payback	yr	6.3
Equity payback	yr	5.5

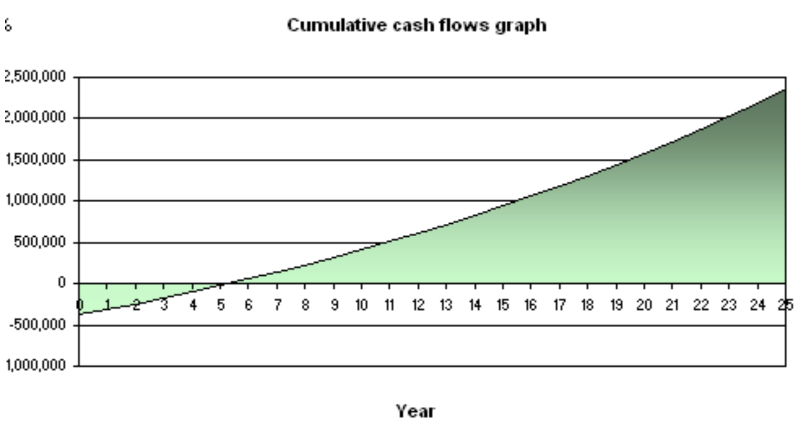


Payback Period = 6.3 yrs

Iteration 6:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⊗	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	90.00	
Manufacturer		Centennial Solar	
Model		a-Si - CS90T	1000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	118.3	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	250	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 30 - 30m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	657	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	980,000
Total initial costs	$	980,000
Incentives and grants	$	600,500
Annual costs and debt payments		
O&M (savings) costs	$	92,450
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	92,450
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	85,279
	$	70,400
Total annual savings and income	$	155,679
Financial viability		
Pre-tax IRR - assets	%	20.9%
Simple payback	yr	6.0
Equity payback	yr	5.3



Payback period = 6.0 yrs

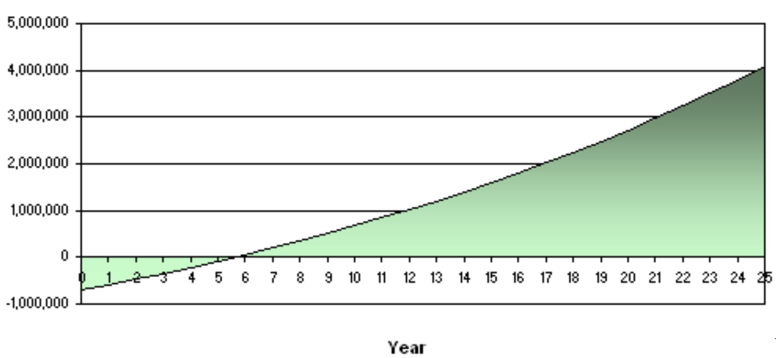
Iteration 7:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type		◉ Method 1 / ○ Method 2	
Photovoltaic #1			
Power capacity	kW	280.00	
Manufacturer		Centennial Solar	
Model		poly-Si - CS280	1000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	367.9	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	160	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 18 - 40m	2 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	420	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,256,000
Total initial costs	$	2,256,000
Incentives and grants	$	1,544,400
Annual costs and debt payments		
O&M (savings) costs	$	69,000
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	69,000
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	91,454
	$	88,500
Total annual savings and income	$	179,954
Financial viability		
Pre-tax IRR - assets	%	19.7%
Simple payback	yr	6.4
Equity payback	yr	5.6

%

Cumulative cash flows graph

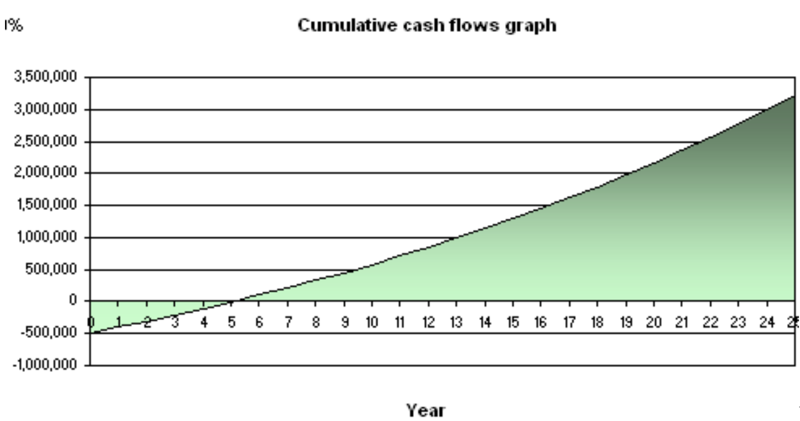


Payback period=6.4yrs

Iteration 8:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦿	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	451.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-205BA3	2200 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	592.6	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	50	
Manufacturer		Entegrity Wind Systems	
Model		EW15 - 25m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	131	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,690,500
Total initial costs	$	2,690,500
Incentives and grants	$	2,200,500
Annual costs and debt payments		
O&M (savings) costs	$	42,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	42,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	79,642
	$	48,400
Total annual savings and income	$	128,042
Financial viability		
Pre-tax IRR - assets	%	21.8%
Simple payback	yr	5.7
Equity payback	yr	5.1

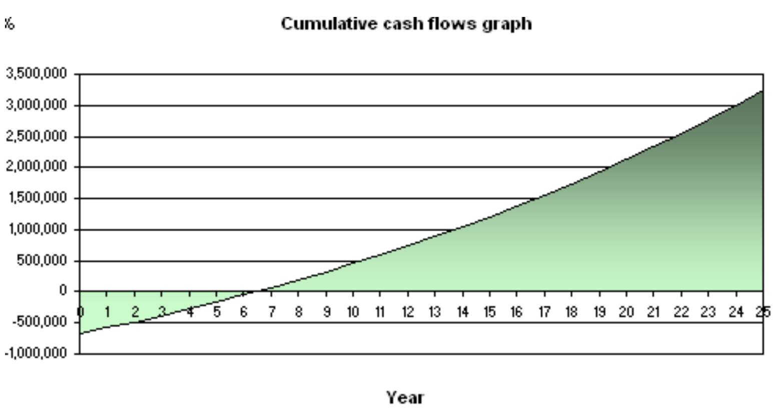


Pay back period = 5.7 yrs

Iteration 9:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦻	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	280.00	
Manufacturer		Centennial Solar	
Model		poly-Si - CS280	1000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	367.9	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	150	
Manufacturer		Atlantic Orient	
Model		AOC 15/50 - 25m	3 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	394	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,215,000
Total initial costs	$	2,215,000
Incentives and grants	$	1,540,500
Annual costs and debt payments		
O&M (savings) costs	$	58,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	58,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	88,406
	$	60,500
Total annual savings and income	$	148,906
Financial viability		
Pre-tax IRR - assets	%	17.2%
Simple payback	yr	7.5
Equity payback	yr	6.4

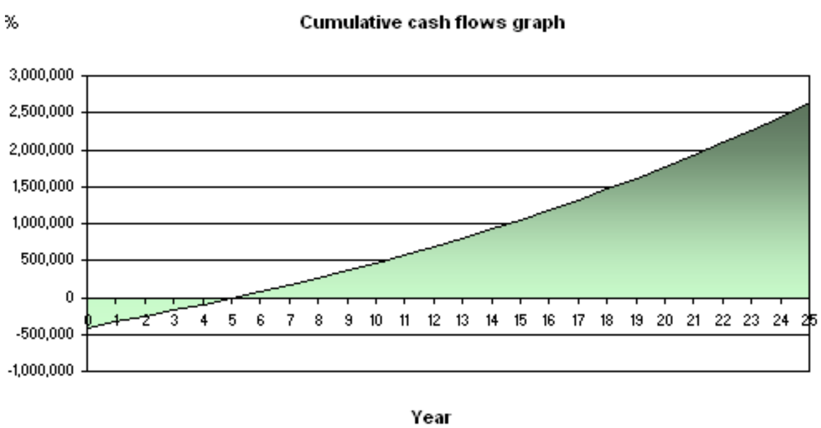


Pay back period = 7.5 yrs

Iteration 10:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⊗	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	90.00	
Manufacturer		Kyocera	
Model		poly-Si - KC60	1500 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	118.3	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	250	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 30 - 30m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	657	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	990,000
Total initial costs	$	990,000
Incentives and grants	$	582,500
Annual costs and debt payments		
O&M (savings) costs	$	83,000
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	83,000
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	90,705
	$	62,500
Total annual savings and income	$	153,205
Financial viability		
Pre-tax IRR - assets	%	21.6%
Simple payback	yr	5.8
Equity payback	yr	5.1

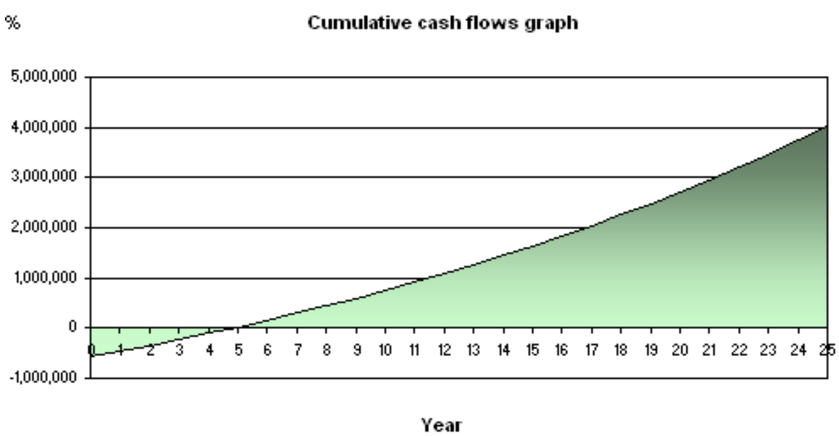


Pay back period = 5.8 yrs

Iteration 11:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦿	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	451.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-205BA3	2200 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	592.6	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	50	
Manufacturer		Bergey Windpower	
Model		BERGEY BWC EXCEL - 36.6m	5 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	131	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,787,500
Total initial costs	$	2,787,500
Incentives and grants	$	2,216,875
Annual costs and debt payments		
O&M (savings) costs	$	32,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	32,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	83,986
	$	54,500
Total annual savings and income	$	138,486
Financial viability		
Pre-tax IRR - assets	%	23.0%
Simple payback	yr	5.4
Equity payback	yr	4.8



Payback period = 5.4 yrs

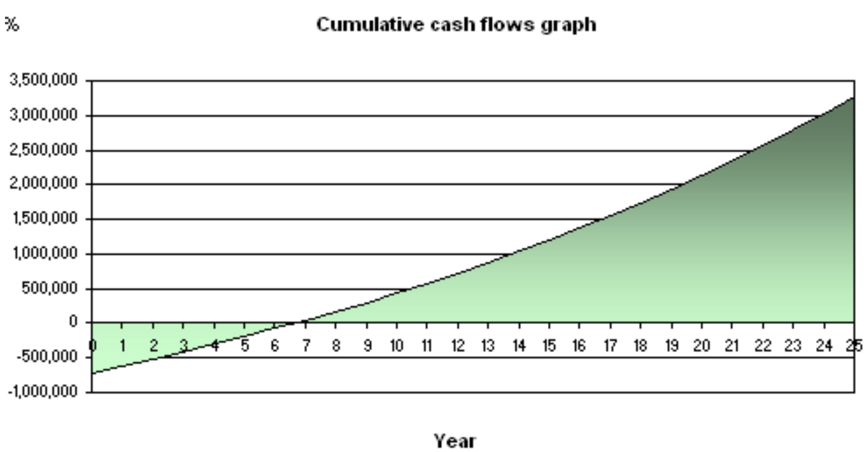
Iteration 12:

Proposed case power system

Base load power system			
Technology		Photovoltaic	
Analysis type		⦿ Method 1	
		○ Method 2	
Photovoltaic #1			
Power capacity	kW	280.00	
Manufacturer		Centennial Solar	
Model		poly-Si - CS280	1000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	367.9	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	160	
Manufacturer		Lagerwey Windturbine	
Model		LAGERWEY 18/80 - 52m	2 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	420	

Financial Analysis

Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,251,000
Total initial costs	$	2,251,000
Incentives and grants	$	1,540,200
Annual costs and debt payments		
O&M (savings) costs	$	72,000
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	72,000
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	91,454
	$	72,500
Total annual savings and income	$	163,954
Financial viability		
Pre-tax IRR - assets	%	16.7%
Simple payback	yr	7.7
Equity payback	yr	6.6

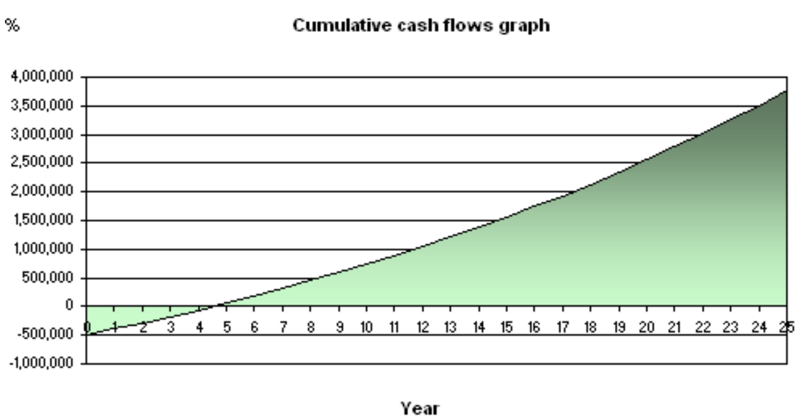


Payback period = 7.7 yrs

Iteration 13:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type		⊙ Method 1	
		○ Method 2	
Photovoltaic #1			
Power capacity	kW	390.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-195BA3	2000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	512.5	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	80	
Manufacturer		Lagerwey Windturbine	
Model		LAGERWEY 18/80 - 52m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	210	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,476,000
Total initial costs	$	2,476,000
Incentives and grants	$	1,980,800
Annual costs and debt payments		
O&M (savings) costs	$	37,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	37,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	79,497
	$	56,500
Total annual savings and income	$	135,997
Financial viability		
Pre-tax IRR - assets	%	24.5%
Simple payback	yr	5.0
Equity payback	yr	4.5



Pay back period = 5.0 yrs

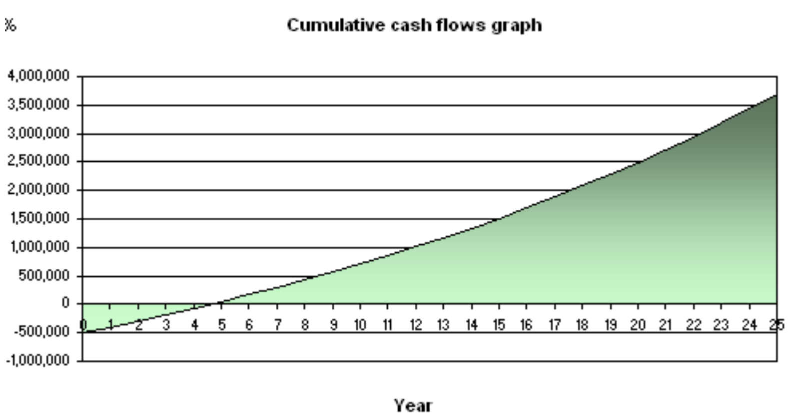
Iteration 14:

Proposed case power system

Base load power system			
Technology		Photovoltaic	
Analysis type	⦿	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	390.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-195BA3	2000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	512.5	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	80	
Manufacturer		Wind Energy Solutions Canada	
Model		WES 18 - 40m	1 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	210	

Financial Analysis

Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,484,000
Total initial costs	$	2,484,000
Incentives and grants	$	1,987,200
Annual costs and debt payments		
O&M (savings) costs	$	39,750
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	39,750
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	83,111
	$	53,200
Total annual savings and income	$	136,311
Financial viability		
Pre-tax IRR - assets	%	24.0%
Simple payback	yr	5.1
Equity payback	yr	4.6

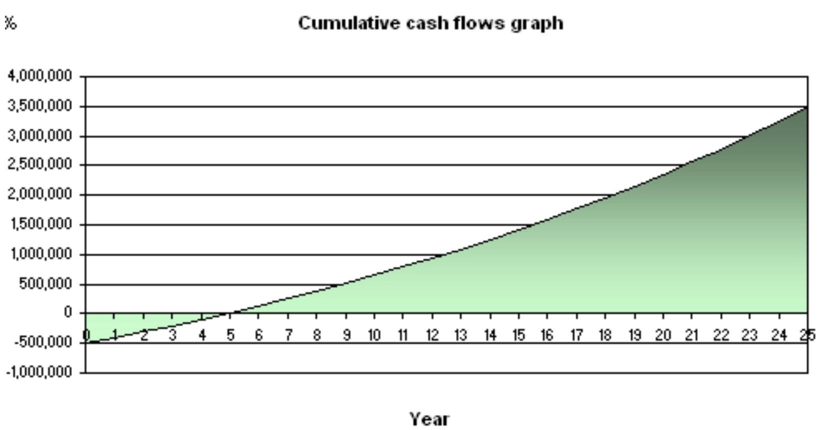


Pay back period = 5.1 yrs

Iteration 15:

Proposed case power system			
Base load power system			
Technology		Photovoltaic	
Analysis type	⦿	Method 1	
	○	Method 2	
Photovoltaic #1			
Power capacity	kW	390.00	
Manufacturer		Sanyo	
Model		mono-Si - HIP-195BA3	2000 unit(s)
Capacity factor	%	15.0%	
Electricity exported to grid	MWh	512.5	
Intermediate load power system			
Technology		Wind turbine	
Wind turbine #2			
Power capacity	kW	80	
Manufacturer		Vergnet	
Model		VERGNET GEV 10/20 - 30m	4 unit(s)
Capacity factor	%	30.0%	
Electricity delivered to load	MWh	0	
Electricity exported to grid	MWh	210	

Financial Analysis		
Financial parameters		
Inflation rate	%	4.0%
Project life	yr	25
Debt ratio	%	0%
Initial costs		
Power system	$	0
Other	$	2,500,000
Total initial costs	$	2,500,000
Incentives and grants	$	2,000,000
Annual costs and debt payments		
O&M (savings) costs	$	45,500
Fuel cost - proposed case	$	0
	$	
Total annual costs	$	45,500
Annual savings and income		
Fuel cost - base case	$	0
Electricity export income	$	79,497
	$	58,000
Total annual savings and income	$	137,497
Financial viability		
Pre-tax IRR - assets	%	22.8%
Simple payback	yr	5.4
Equity payback	yr	4.8



Pay back period = 5.4 yrs

APPENDIX C(i) : **Availabe Models (Photovoltaic Database)**

Based on different types, the different options available are:

a-Si, CdTe, CIS, mono-Si, poly-Si and other Canadian Solar types. The shaded ones have been used.

Under a-Si types, we have the following options:

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
BP Solar	BP Millenia MST 50 MV	50	6.1%	0.82
	MST 43LV	43	5.22%	0.82
Centennial Solar	CS40T	40	6.6%	0.6
	CS90T	90	6.2%	1.45
EPV	EPV20	19	4.81%	0.4
	EPV40	40	5.06%	0.79
Uni-Solar	22-L-B/22-L-T	128	5.9%	2.16
	ASR -128W	128	5.65%	2.27
	ES-124W	124	6.36%	1.95
	PVL-136W	136	6.3%	2.16
	SSR-128W	128	5.65%	2.27
	Uni-Pac 15W	15.8	1.84%	0.86
	US-64W	64	6.32%	1.01
	USF-32	38	5.28%	0.61

Across each of the manufacturer, only the unique category cells are being mentioned.

For CdTe:

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
BP Solar	Apollo 980	80	8.6%	1.21
First Solar	CdTe Type	50	6.94%	0.72

For CIS:

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
Centennial Solar	CIGS50	50	6.6%	0.75
Shell (Germany)	ST40W	40	9.43%	0.42

For mono-Si:

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
BP Solar	2150S	150	11.9%	1.26
	250F	50	11.44%	0.44
	BP4175	175	13.9%	1.26
	590F	90	14.29%	0.63
Day 4 Energy	36Mono 155	155	15.67%	0.99
	48 Mono200	200	15.44%	1.3
Energias Renovaveis Portugal	Enepowerone GSS5-180°-E	180	13.97%	1.3
GE	AP 120	120	12.32%	0.97

	GEPV 110-M	110	11.4%	0.96
Isofoton	I-165	165	13%	1.27
RWE Schott Solar	ASE-300-DG/50	285	11.74%	2.43
Sanyo	HIP-186BA3	186	15.8%	1.18
	HIP-205BA3	205	17.4%	1.18
	HIP-J50B1	180	15.24%	1.18
	HIP-195BA3	195	16.5%	1.18
Sharp	NT-175U1	175	13.45%	1.3
	NT185-U1	185	14.22%	1.3
Shell	SM110-L	110	12.91%	0.85
	SM55	55	12.93%	0.43
	SP75	75	11.9%	0.63
	SQ 160-C	160	12.12%	1.32
	Ultra-85-P	85	13.4%	0.63

For Poly-Si:

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
BP Solar	AC power Wall	220	10.39%	2.12
	BP 3165	165	13.1%	1.26
	MSX 120, 24V	120	10.9%	1.1
	SX 150S	150	11.9%	1.26
	MSX -83	83	11.33%	0.73
	VLX 53	53	11.28%	0.47
Canadian Solar	CS6A-180	180	13.8%	1.3
	CS6P-240	240	14.9%	1.6
Centennial Solar	CS115	115	14.3%	0.99

	CS15	15	9.8%	0.15
	CS280	280	14.4%	1.94
Day 4 Energy	36MC 115	115	11.63%	0.99
	36MC 145	145	14.66%	0.99
	36MC 190	190	14.67%	1.3
Energy Solutions SA	ES630/QP140	140	14.3%	1
(Greece)	ES660/QP235	235	14.8%	1.63
Evergreen Solar	ES 240	220	7.29%	3.02
ICP Solar Technologies	SolarPRO plug'n'play@300W	300	9.94%	3.02
	SolarPRO plug'n'play@100W	100	9.18%	1.09
Kyocera	KC120-1	120	12.9%	0.93
	KC60	60	12.25%	0.49
	KC80-2	72	10.97%	0.66
Matrix Solar Technologies	PW500,52	52	11.2%	0.47
	PW1250-135W-18V	135	13.28%	1.02
Mistubishi Heavy Industries	Superstratum 123	123	12.3%	1
Photowatt	PW500-1	52	11.2%	0.47
Sharp	ND-070ELU	70	6.07%	1.15
	ND-L3EJE	123	12.39%	0.99
	NE-L5E3H	125	13.3%	0.96
Shell	IRS 75MA	73	11.6%	0.65
	RSM70	68	9.6%	0.71

	RSM 115	113	11.6%	1.04
	RSM 80	78	11%	0.71

For Spherical –Si: No models in database

Other :

Manufacturer	Model	Capacity per unit (W)	Efficiency	Frame (m^2)
Canadian Solar	CS4A-150	150	13.09%	1.28
	CS4D-55	55	14.4%	0.46
	CS5A-175	175	15.56%	1.28
	CS6C-120	120	14.81%	0.93

APPENDIX C(ii) : **Availabe Models (Wind Turbine Database)**

Based on different types, the different options available are:

Manufacturer	Model	Capacity per unit (kW)	Hub-Height (m)	Rotor diameter (m)	Swept area per turbine (m^2)
Atlantic Orient	15/50 30m	50	30	15	176.71
Bergey WindPower	BWC Excel	10	36.6	7	38.48
Clipper WindPower	Liberty Wind Turbine(Class IIIA)	2500	80	99	7698
DeWind	Dewind 41	500	40	41	1320.25
	Dewind 46	600	40	46	1661.9
Enercon (Portugal)	Enercon 40	500	50	40	1256.64
Energie PGE (France)	PGE 20/25	25	37	20	305
Entegrity Wind Systems	EW15	50	25	15	176.17
Eoltec SAS (France)	Scirocco E5.6-6	6	30	5.6	24.6
Gamesa	G52 RCC	800	55	52	2123.72
GE	Wind 750 -46	750	55	46	1661.9
	Wind 750-48	750	55	48	1809.56
	Wind 750-50	750	55	50	1963.5
Husumer	HSW 1,000/57	1050	55	57	2551.76
Jeumont	J48-CL1	750	46	48	1809.56
Lagerwey Windturbine	18/80	80	52	18	254.47
	30/250	250	50	30	706.86
	50/750	750	50	50.5	2002.96

Made Energias	AE-52	800	50	52	2123.72
(Gamesa)	AE-30	330	30	30.4	725.83
Mitsubishi Heavy Industries	MWT-450	450	50	39	1194.59
Nordex (Germany)	N43	600	50	43	1452.2
Northern Power Systems	NW100/21	100	40	21	346.36
REPower	RePower 48	600	50	48.4	1839.84
Siemens	AN BONUS 1MW	1000	50	54.2	2307.22
	AN BONUS 300KW	300	40	33.4	876.16
	AN BONUS 600KW Mk IV	600	50	44	1520.53
Sustainable Energy Technologies	Chinook 2000-VAWT	250	16.59	21.5	420
Suzlon	S. 33/350	350	50	33.4	876.16
Vergnet	GEV 15/60	60	40	15	176.71
	GEV 10/20 -18	20	18	10	78.54
	GEV MP32	275	55	32	804.14
Vestas	NEDWIND NW41	500	65	40.77	1305.48
	MNM 600/43	600	56	43	1452.2
	V90-3.0MW	3000	90	90	6361.73
	NEDWIND NW31	250	43	31	754.77
Wind Energy Solutions Canada	WES 30	250	50	30	707
	WES 18	80	40	18	254
Windtec	Windtec 650	600	51.5	50	1963.5

APPENDIX D : **TRENDS**

Electric Power Annual 2007 Released: January 21, 2009

Energy Source	**Number of Generators**	**Generator Nameplate Capacity**	**Net Summer Capacity**	**Net Winter Capacity**
Coal	1,470	336,040	312,738	314,944
Petroleum	3,743	62,394	56,068	60,528
Natural Gas	5,439	449,389	392,876	422,184
Other Gases	105	2,663	2,313	2,292
Nuclear	104	105,764	100,266	101,765
Hydroelectric Conventional	3,992	77,644	77,885	77,369
Wind	389	16,596	16,515	16,541
Solar Thermal and Photovoltaic	38	503	502	422
Wood and Wood Derived Fuels	346	7,510	6,704	6,745
Geothermal	224	3,233	2,214	2,362
Other Biomass	1,299	4,834	4,134	4,214
Pumped Storage	151	20,355	21,886	21,799
Other	42	866	788	814
Total	**17,342**	**1,087,791**	**994,888**	**1,031,978**

Table 1: Existing Capacity by Energy source

Official Energy Statistics from the U.S. Government, Energy Information Administration

http://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.html

Planned Nameplate Capacity Additions from New Generators, by Energy Source, 2008 through 2012

Energy Source	2008	2009	2010	2011	2012
Coal	1,131	6,082	4,996	4,514	6,624
Petroleum	90	1,045	55	720	--
Natural Gas	9,780	12,334	8,911	6,919	10,156
Other Gases	--	--	--	--	--
Nuclear	--	--	--	--	1,270
Hydroelectric Conventional	18	6	6	204	2
Wind	9,821	3,661	1,045	90	--
Solar Thermal and Photovoltaic	23	127	315	1,050	880
Wood and Wood Derived Fuels	32	60	68	14	114
Geothermal	138	30	87	128	--
Other Biomass	173	129	1	122	2
Pumped Storage	--	--	--	--	--
Other	22	--	--	--	--
Total	**21,226**	**23,475**	**15,484**	**13,762**	**19,049**

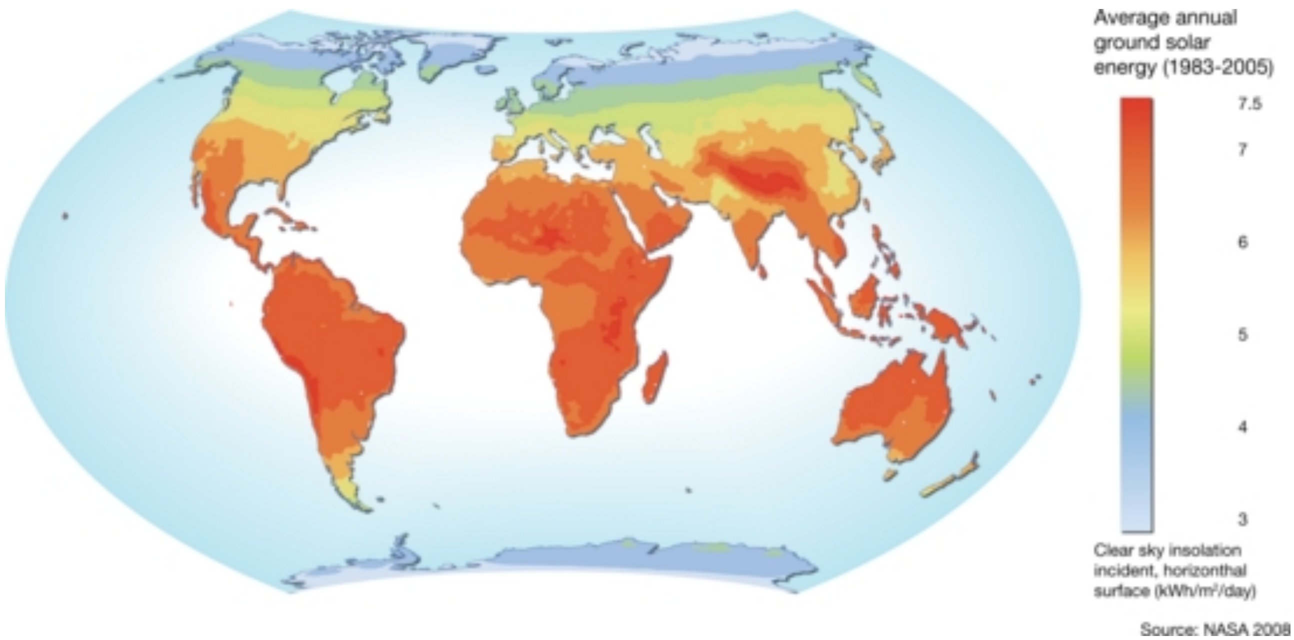
Table 2: Planned Nameplate Capacity Additions from New Generators, by Energy Source, 2008 through 2012

Official Energy Statistics from the U.S. Government, Energy Information Administration

http://www.eia.doe.gov/cneaf/electricity/epa/epat2p4.html

APPENDIX E : **Solar Energy**

Natural Resource – Solar Power Potential

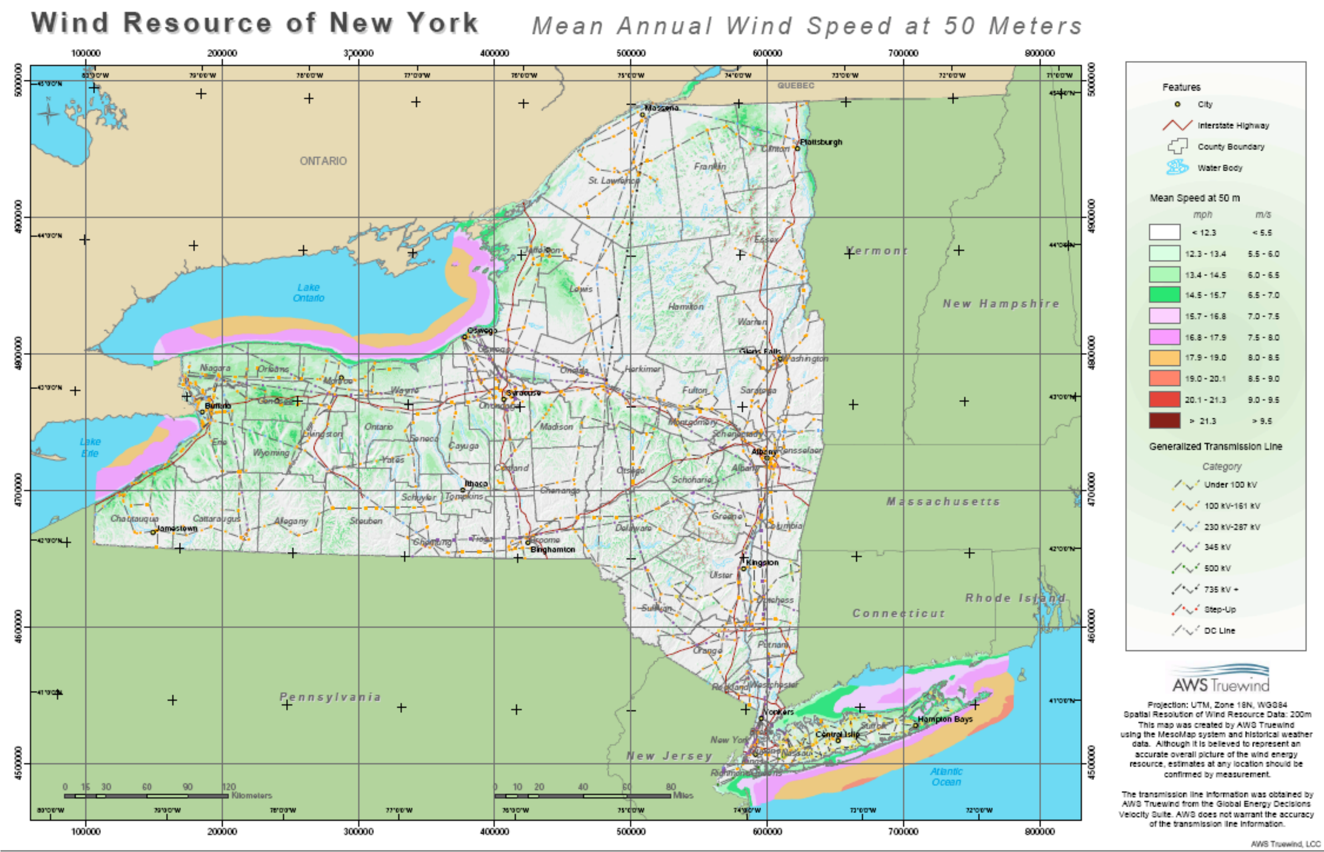


Natural resource - solar power (potential). More than two billion people cannot access affordable energy services today. They depend on inefficient locally collected and often unprocessed biomass-based fuels, such as crop residues, wood, and animal dung. Because convenient, affordable energy can contribute to a household's productivity and income generating potential, its availability can help families and communities break out of the cycle of poverty. At the same time it also provides growing cities of the world the life source that powers Internet cafés, factories, schools and streetlights. Modern renewable energy technologies such as solar-, wind-, micro-hydro and geothermal power remain largely untapped, despite the relative abundance of sunshine, wind, water and underground thermal heat. The map is a part of a set, presenting different natural resources, with a focus on developing countries, and the use of natural resources for economic growth and poverty alleviation.

REF:

Natural resource - solar power (potential). (2008). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 05:23, April 28, 2009 from http://maps.grida.no/go/graphic/natural-resource-solar-power-potential.

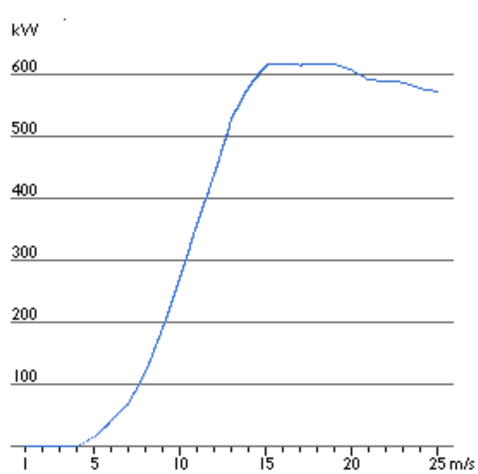
APPENDIX F: **Wind Energy**



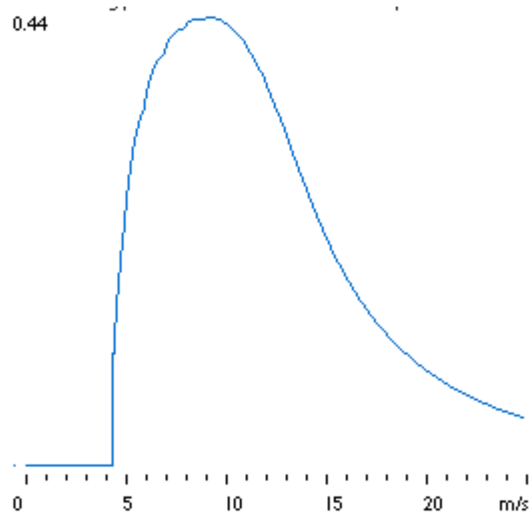
Map 1: wind Speed of New York at 50 meters = 6.1m/s

Map 1: http://www.awstruewind.com/files/NY_spd50m.pdf

Wind power Curve as obtained from http://www.windpower.org/en/tour/wres/pwr.htm



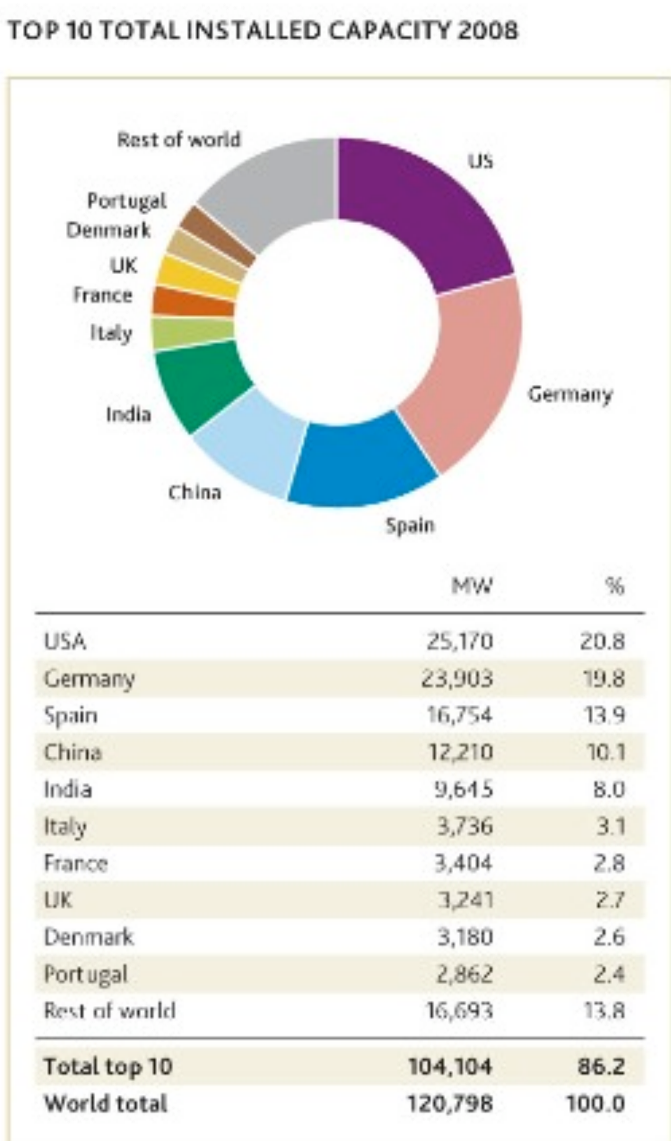
The power coefficient tells you how efficiently a turbine converts the energy in the wind to electricity. The curve is obtained from windpower.org website.



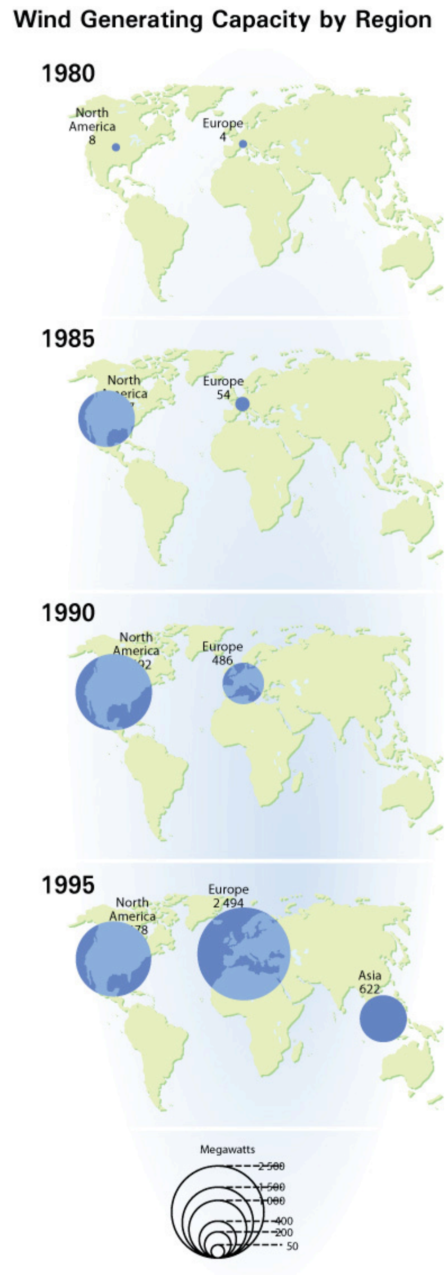
The different prices of wind turbines can be found at http://www.windpower.org/en/tour/econ/index.htm

Wind is a global power resource and we should harness the power of wind as much as possible.

The total installed capacity of wind energy is shown in the graph below as obtained from Global Wind Energy Council at http://www.gwec.net/index.php?id=13.



	MW	%
USA	25,170	20.8
Germany	23,903	19.8
Spain	16,754	13.9
China	12,210	10.1
India	9,645	8.0
Italy	3,736	3.1
France	3,404	2.8
UK	3,241	2.7
Denmark	3,180	2.6
Portugal	2,862	2.4
Rest of world	16,693	13.8
Total top 10	**104,104**	**86.2**
World total	**120,798**	**100.0**



Regional Trends in Wind Power Generation

Wind power remains one of the cleanest alternatives to fossil fuels and nuclear power. Wind energy generating capacity, trends in the period 1980-1995, in megawatts for Asia, Europe and Northern America.

REF: Regional trends in wind power generation. (1997?). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 05:32, April 28, 2009 from http://maps.grida.no/go/graphic/regional_trends_in_wind_power_generation.

WIND

The Wind capacity has been constantly on the rise in the US. In the table given below, We can clearly observe that the Total Installed Capacity has risen from 2578MW to 25,170MW which is ten-fold.

Total Installed Capacity									
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
MW	2,578	4,275	4,685	6,372	6,725	9,149	11,575	16,824	25,170