Renewable Energy-Hydrogen Cycle

A 24 Hour Solution for Variable Alternative Energy

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Definitions

Average Renewable Day:	The average number of hours per day in a given month of production of renewable energy.
CPV :	Concentrated Photovoltaic, a type of solar pannel that magnifies solar radiation, requires direct sunlight
DNI:	Direct Normal Irradiance, a measurement of light energy a given area receives
Electrolysers:	Machines that use electroloysis to break water apart into hydrogen and oxygen.
Heat Rate:	The amount of thermal energy needed to produce a unit of electrical energy
IDE:	A Reverse Osmosis Manufacturer
IHT:	An electoryser manufacture based out of Switzerland
LHV:	Lesser heating value, the amount of heat burring a compound will yield, for this report LHV refers to the LHV of hydrogen which is 290 BTU’s per normal cubic foot of hydrogen gas
MST:	A CPV and TPV manufacturer. Their trackers are some of the most advanced in the world.
MW:	Megawatt, 1,000,000 watts of electrical energy
NOAA:	National Oceanic and Atmospheric Administration, their data is used for all U.S. sights to determine cloud cover and weather.
Renewable Energy Source:	Any renewable energy that provides variable output that is used to provide power for the system to function.
Revised Heat Rate :	A derived heat rate that takes into account additional energy produced by the co-generation turbines
R.O.:	Reverse Osmosis, a process which clarifies water thru the use of semi-permeable membranes
Stated Plant Output:	The minimum amount of power that must be continuously generated by the plant at all times

Solar Field:	The entire array of solar panels installed for a given project.
TPV:	Thermal Photovoltaic, a type of solar panel that takes radiant energy from the sun and converts it to electricity
Weather efficiency:	A number in percent to quantify the average number of cloudy days in a month. Used to as part of the equations to determine "average solar day"

General Concept

In order to provide continuous 24 hour power with renewable variable energy this process uses hydrogen as a storage mechanism to store excess energy generated from the renewable energy source. Hydrogen is created thru electrolysis where electricity is used to break water into its component hydrogen and oxygen atoms. The stored energy in the form of hydrogen is then burned in gas turbines to produce electricity when the renewable energy source is non-functional. Depending on local needs the plant is also capable of producing domestic water and potentially reclaiming water as well. The process has the ability to provide power, fresh water distribution and water treatment.

Plant Facilities

The major elements of the Renewable Energy-Hydrogen Cycle are described in this “Plant Facilities” section. Plant operation is described in Section “Plant Process Description” and “Methodology”.

Renewable Energy Source:

Energy is produced through non-constant renewable energy any source or combination of renewable energy may be used, including Wind, Solar, Tidal, or any other as yet unknown technology that produces variable electric power.

Wind Farm:

The Wind Farm consists of multiple windmills with attached generators to produce power. Various companies such as Siemens and G.E. make wind turbines suitable to utility scale applications.

The Wind Farm is sized using two factors, energy demand, and productivity. Demand on the farm is created from three sources, the hydrogen plant using electricity to store energy, electricity to end user, and if applicable electricity sales to the grid. Productivity is determined by the average amount of wind that the farm receives in a given month.

Solar Field:

The solar field consists of either CPV or TPV solar arrays. Double axis trackers such as those developed by MST are preferred due to their increased efficiencies but not necessary. CPV arrays are best suited for solar intense areas where cloud cover and inclement weather is minimal. CPV technology reduces the land area required for energy production requiring only 2.5 to 2.96 acres per MW depending on topography. TPV is better suited for non-optimal solar locations. Areas with higher average cloud cover will fare better using TPV technology. The draw-back to TPV is a larger land use requirement at 3.6 acres per MW.

The field size is determined by two factors, energy demand and weather. Demand on the solar field is created from three sources, the hydrogen plant using electricity to store energy, electricity to end user, and if applicable electricity sales to the grid.

Water Sources:

Water can be obtained in a variety of ways to support plant operations. Ground water, sea water, domestic water, and even reclaimed water can all be used as a primary source for both cooling and hydrogen feed water. All water regardless of its source is processed thru a reverse osmosis facility to remove any impurities that might damage plant equipment. In the event domestic water is used all chlorine and fluorine must be removed prior to treatment to prevent damage to the membranes in the reverse osmosis facility.

The plant can be designed to accommodate both power and water demands. The reverse osmosis plant can be sized to include domestic water production as well as the necessary water for all electrolysis and cooling. In the event that domestic water is needed additional water storage must be taken into account.

Hydrogen Generation:

Hydrogen is produced thru electrolysis. Electrolysis is the process by which low voltage electricity is used to break apart a water molecule into hydrogen and oxygen. Fresh water electrolysis yields only hydrogen and oxygen, with no other byproducts.

Companies such as IHT or NEL are currently the best suited for utility scale hydrogen generation. IHT produces alkaline electrolysers capable of producing 760 normal cubic meters of hydrogen gas an hour at a pressure of up to 450 PSI (32 bar). IDE produces similar electrolysers but they are only capable of producing 500 normal cubic meters at pressures of no more than 1 bar. IHT's electrical demand is quoted at 4.3 to 4.6 KWh per normal cubic meter of hydrogen produced, while NEL's electrolysers only require 4.1 to 4.3 KWh per cubic meter of hydrogen produced.

Water has two uses in the electrolyser, both as a hydrogen source as it is broken down, and in cooling the elctrolyser to prevent overheating. IHT electrolysers require 40 liters of cooling water per normal cubic meter of hydrogen gas produced. They also require 0.85 liters of feed water per normal cubic meter of hydrogen produced. NEL has not published their cooling water requirements.

The electrolysers cells are quoted as having an expected life of 10 to 15 years under full production. Our plant will only be using the electrolyzers on average 6 to 8 hours a day this should triple the lifespan. This makes replacement of the electrolyzesr cell blocks very unlikely during the lifespan of the plant.

Hydrogen Gas Storage:

Hydrogen is stored in high pressure vessels at 1500 PSI (105 bar). Prior to entering the high pressure vessel the hydrogen pressure is raised from 450 PSI (32 bar) to 1500 PSI (105 bar) to minimize storage volume.

Sizing the storage field is a function of weather and electrical demand. Using weather data we determine the 100 year maximum of consecutive cloudy days that hydrogen would be required to run the gas turbine facility on a 24 hour basis while the solar field is non-functional.

Safety is ensured through industry standard practices. All high pressure gas lines will be double walled with hydrogen detection equipment installed. Valves to each tank will be automatic shutoff systems with automatic pressure loss sensors to isolate any tank that might develop a leak.

Gas Turbine:

Gas turbines will use hydrogen gas instead natural gas as a fuel. Studies have already been done using hydrogen as a gas turbine fuel with Siemens gas turbines. The report in the Journal of Engineering for Gas Turbines and power, January 2005 Vol 127 titled "Using

Hydrogen as Gas Turbine Fuel" indicates that the Siemens turbines will only require minor adjustments to compensate for hydrogen as a fuel. This leads us to believe that most Siemens gas turbines will be suitable for our process. We have engaged in a preliminary dialogue with Siemens regarding the possibility of using hydrogen as a fuel for their gas turbines. We have not fully disclosed our process to them, and will not until we have started the patent process. Preliminarily Siemen's has indicated that some of their units currently do run on hydrogen, and they have ongoing research. However, Siemen's turbines are not the only ones that would work; any Gas Turbine that is capable of burning hydrogen will work.

Turbine sizing is determined by overall energy demand with a projected minimum size demand of 20MWh. Upper demand has virtually no limit as multiple large turbines can be used in series. Siemens gas turbines come in a wide range of sizes from 10 MW to 300 MW.

NOX emissions are verified by Siemens to be approximately 40PPM or below when using hydrogen as a fuel. We do not believe that at this level NOX emissions are a significant factor. In the event that the turbine chosen has significant NOX emissions, a NOX scrubber plant can be constructed to reduce NOX emissions to an acceptable level.

Co-Generation System:

The co-generation system is designed to recover exhaust heat from the gas turbines and convert it into electrical energy. The size and type of the Co-generation System used is determined by the heat rate of the Gas Turbine(s) being used. For example, on smaller installation Pratt & Whitney Turboden generators that recover exhaust thru heat exchangers and provide up to an additional 12 MW per unit installed can be used. Depending on the size of the Gas turbine multiple Turboden units may be attached to each Gas Turbine. In our conversations with Pratt & Whitney this system has been used with Siemens Gas Turbines previously and all necessary equipment, including heat exchangers and chillers are included in their installation. Larger installation can use a high pressure steam turbine as a cogeneration unit. .

Control Room/Switching Station:

The control room is responsible for day to day plant operation, including:

Internal plant electricity distribution

Electricity distribution to grid and or end user

Hydrogen Production

Hydrogen Storage

Gas Turbine Operation

Reverse Osmosis Plant Operation

Safety Monitoring

Cooling System Monitoring

Computer control and monitoring is the heart of the control room, with many of these functions being automated to ensure reliable operation as well as reduce overhead costs.

Cooling System:

Three methods of cooling are available for cooling the electrolysers and hydrogen compression, cooling towers, chillers, and a cooling ponds. Each system is site specific depending on temperature, humidity and water availability. The cooling towers are the most efficient but use large amounts of water, and can only be used efficiently in arid climates. Chillers have a minimal water requirement but do use a noticeable amount of electricity. A cooling pond uses no electricity, is not as efficient as a cooling tower but has a much lower capital cost than the other two methods and can be designed to provide a potential ecological benefits to the area it is installed in.

Plant Process Description

During daytime operation power from the solar field is collected at the solar substation where voltage is increased and prepared for distribution. The facility control room then determines where power is needed in the plant; in the event that there is excess power from the solar field it is sold to the grid if available. It is the control rooms' responsibility to determine which elements of the plant are currently active, each plant element can be separately activated and run independently. Necessary power for each element is then routed from the solar substation to the active plant facilities

Hydrogen production begins with the water produced by the reverse osmosis plant. The non-treated water is pumped to primary storage for use in the reverse osmosis plant. In the event domestic water is used all fluorine and chorine must be removed prior to use in the reverse osmosis facility to avoid damaging the membranes. Two days of reserve non-treated water are stored in the event of an interruption in water supply. After treatment in the reverse osmosis facility the water is pumped to secondary storage. Two days of secondary storage are also maintained. All storage is maintained automatically by the control room via float systems in the storage tanks. Water required by the electrolysers is routed via automatic valves operated by the control room. As part of the electroloysis process cooling water is required at a rate of 40 liters per normal cubic meter of hydrogen gas produced or 0.3 gallons per normal cubic foot of hydrogen gas produced. As with the feed water, cooling water is also activated via automatic valves and a pump system. Cooling water is circulated thru the electrolysers and routed through a cooling process that reduces cooling water temperature by 36 degrees Fahrenheit. In our model we have chosen a cooling pond over chillers or cooling towers. The cooling pond is designed to be functional as well ecological. In this model we estimate that a pond of 16 acres with a depth of six feet to be sufficient for all cooling needs. This calculation is based on an ambient temperature of 85 degrees with 20 percent average relative humidity. Water circulation thru the electrolysers occurs only during hydrogen production. During summer months the electrolysers only operate for 8 hours a day due to decreased demand thus lowering cooling requirements during the hottest times of the year.

The electrolysis process yields only hydrogen and oxygen with no other by-products. Hydrogen produced has a purity of 99.8% and thus requires no further refinement to be used as a fuel. Oxygen has a similar purity and if there is a need for it can bottled and marketed, if not it is released back into the atmosphere. The hydrogen is pre-compressed in the electrolyser to 450 PSI (32 bar) and then shipped to the hydrogen storage area. Prior to entering storage tanks the pressure of the hydrogen gas is increased to 1500 PSI (105 bar) in preparation for storage. The storage field consists of multiple high pressure gas storage tanks isolated from each other and connected by a valved header system. The valved header system allows the control room to pressurize each tank individually and monitor the pressure in all tanks constantly. All high pressure piping will be double walled with hydrogen gas sensors between walls to detect any leaks. In critical areas parallel system of piping will be installed to ensure continuous plant operations. The overall size of the hydrogen storage field is determined by weather and demand as noted in methodology.

Hydrogen from the storage tanks is then routed to the gas turbines. Hydrogen can be drawn from any tank. A master control valve regulated by the control room determines when gas is allowed to flow to the turbines. The Gas turbines require hydrogen gas at approximately 400 PSI (30 bar) to facilitate this a regulator and pump system are needed to maintain constant pressure to the turbines. The regulator reduces the pressure to 400 PSI (30 bar) in the event that the stored gas pressure is above that. When the storage tanks pressure is lower than 400 PSI (30 bar), an additional compression pump is required to maintain operating pressures. Each turbine has its own automatic valve system to allow independent operation controlled by the control room. Turbine operation only occurs when the solar field is inactive due to night or weather. Hydrogen production only occurs while the solar field is active and therefor never occurs when the turbines are active.

The turbines operate in the same manner as a jet engine. Fuel is burned in a combustion chamber. Gas rapidly undergoes thermal expansion, greatly increasing the pressure. The exhaust gases are used to turn a multiple bladed turbine that creates rotational energy. The rotational energy is transferred through a drive shaft to an electrical generator. The excess heat from the exhaust gasses is captured and sent to a heat exchanger for use in the co-generation turbines. In our case study the SGT-800 produces 289.9 pounds per second of exhaust at 1011 degrees F. The co-generation turbines operate by using a thermal oil in a closed hydraulic system to generate rotational energy that is then used in an electrical generator. The combined energy from both generators is collected at an electrical sub-station where it is prepared for distribution to the end user.

The following diagram shows the plant operations visually in a flow chart. (Exhibit A) A sewer treatment plant facility is also shown in this diagram; this facility is optional and decreases the demand for water as well as providing another service.

Methodology:

The Solar-Hydrogen cycle is a method by which alternative green energy can provide 24 hour power 365 days a year to a specific user or to the grid. The system uses any renewable source to produce hydrogen gas that will operate gas turbines when the renewable source is inactive. Renewable source and plant design is site specific and depends upon the amount of production of the renewable source, the type and amount of water available, location of the grid and interconnect, and the minimum amount of continuous 24 hour power to be produced.

The system operates with the renewable source providing power for hydrogen production and storage as well as providing the continuous power required by the end user or the grid. Therefore, the renewable source must be sized to produce enough power to produce hydrogen during that portion of the year when the renewables source's productivity is lowest. For modeling purposes the "average renewable day" for every month is determined. During the shortest "average renewable day" of the year hydrogen production is slightly more than is needed to operate the gas turbines during the projected renewable energy source downtime. The excess hydrogen is sent to a storage facility for use when the renewable energy source is inactive. Storage volumes are determined by evaluating frequency that the renewable energy source is non- productive during the shortest "average renewable day". A safety factor of 1.25 is applied to the average expected downtime of the renewable energy source.

The hydrogen demand is determined by the amount of power needed to maintain "stated plant output" while the renewable energy source is non-operational. The time expressed by (T), the solar field is non-operational is determined by subtracting the "average renewable day" of any given month from 24 hours. Power is produced during solar down time by the Gas Turbines which must burn hydrogen to produce power. The amount of hydrogen used by the turbines as fuel is determined by the heat rate of the turbine. Siemens expresses this number in BTUs per KWh and varies from generator to generator. To determine the total number of BTUs required to operate the gas turbine the equation, $HR \times T = TH$ where HR is the heat rate, T is time, and TH is the total heat required in BTUs. However the power from the co-generation units must be taken into account, to do this the equation $TH/TP=RHR$, where TH is the total heat from the gas turbines in BTUs, TP is total power produced by both the gas turbine and the co-generation system, and RHR is the revised heat rate. The revised heat rate is then multiplied by the LHV of a normal cubic foot of hydrogen gas to determine the amount in normal cubic feet hydrogen needed to produce a KWh of power. This number is then multiplied by the "stated plant output" and T to determine the average hydrogen demand per day for the given month.

The renewable power source size is determined by the amount of power necessary to produce the hydrogen thru the electrolysis process. The electrical demand is given by IHT as 4.3 to 4.65 KWh per normal cubic meter of hydrogen. All of our measurements are in the English measurement scale so it is necessary to convert normal cubic meters to normal cubic feet, to do this multiply by 35.31. A result of 4.3 to 4.65 KWH per 35.31 normal cubic feet is the result. After simplification we yield a result of 8.21 to 7.59 normal cubic feet per KWh. We choose to use the more conservative number of 7.59 normal cubic feet per KWh when determining the power demand to generate hydrogen. The number of cubic feet of hydrogen used on an average day in a given month is then multiplied by the 7.59 KWh per cubic foot to determine an average daily power requirement per month for the solar field to generate hydrogen. The field is then sized to the highest average daily hydrogen power required plus the demand for "stated plant output".

Water requirements are based on hydrogen demand and cooling requirements. As stated above IHTs electrolysers require 0.85 liters per normal cubic meter of hydrogen produced. After converting to the English scale this yields 6.36 gallons per 1000 normal cubic feet of hydrogen. A feed water requirement is then derived by dividing 6.36 gallons per 1000 normal cubic feet of hydrogen into the average daily hydrogen demand. IHTs electrolysers also require 40liters per normal cubic meter of cooling water, or about 0.3 gallons per normal cubic foot of hydrogen produced. This water must be cooled a minimum of 38 degrees Fahrenheit. In our model we have chosen to use a cooling pond which functions primarily using evaporation as its cooling method. The makeup water for the pond is determined by series of equations which can be found in “Surface Heat Loss From Cooling Ponds” . The total daily water requirement is the pond make up water plus the hydrogen electroylser feed water.

The control room is responsible for ensuring all day to day plant operations. Computer programs will be married and altered to provide automatic functioning. We are currently reviewing potential software companies to write a single unified program that will automate as much of the process as possible. The program needs to accommodate both daytime and nighttime operation. During daytime operation the control room will monitor power produced from the solar field, distribute power from the solar field internally and potentially to the grid, monitor cooling temperatures, regulate hydrogen production, and control hydrogen gas distribution into the storage facilities as well as all safety monitoring to ensure that there are no hydrogen leaks.

If the renewable source is solar, daytime operation begins at daybreak, when the solar field first starts to receive sun light and produce power. The control room automatically recognizes the power increase from the solar field and begins the shutdown process for the gas turbines. Until the solar field has reached “stated plant output” the gas turbines remain online. After “stated plant output” has been reached by the solar field commands are sent to begin hydrogen production. The hydrogen production process begins by simultaneously opening cooling and feed water valves and activating the necessary pumps associated with those functions. As power from the solar field continues to increase and drawdown on stored processed fresh water begins the control room then initiates reverse osmosis facility operations. All water storage tanks will be equipped with a float system that will monitor storage volume. Reverse osmosis will continue until the storage tanks are full or there is insufficient power from the solar field to continue operations. If domestic water production is required the plant can be designed to run the reverse osmosis plant continuously as need.

In the event of interruption of power production on the solar field due to partly cloudy weather, the control room software is designed to recognize the rate of decline and percent of total field output loss. At a certain point the rate of decline and the limited remaining production will trigger gas turbine start up to compensate for the loss of solar production. The plant operator has the ability override the computer system. In the event of continued intermittent loss of solar production, the plant operator has the ability to override software protocol and maintain gas turbine production to prevent numerous startups and shutdowns of the gas turbines. The operator must be aware of weather events that would cause a rapid decline in solar production compensating for that condition by initiating gas turbine start up prior to loss of solar production. The spin up time for most Siemens turbines is 6 to 8 minutes.

If the renewable source is wind, the control room must constantly monitor power production from the Wind Farm, and supplement any loss of production with power from the Gas Turbines.

Economic Methodology:

The economic model is based on an assumed 30 year plant life. Total costs are determined by adding the costs of all of the component parts of the plant. Only a solar economic model has been run as that is the renewable energy source we have seen the most interest in.

The cost of the solar field is determined by the total number of panels to be installed. The total number of panels to be installed is determined by the output of each panel divvied into the total output needed. MST's CPV solar panel produces 30KWh in direct sunlight, therefor a plant requiring 5 megawatts of solar power would need 167 solar panels as an example. Each MST tracker costs $80,000 to produce and $10,000 to install. This price is somewhat flexible and larger order may receive a price break.

The Gas Turbine are manufactured by Siemens and the cost is determined by the number and model of the turbines used. In our case study we use the SGT-800 turbine with a cost 25 million dollars installed.

The cost of cogeneration turbines will also be based on number and type used. In our case study we use Pratt&Whittney Turboden co-generation turbines. Each unit has an installed cost of 17 million dollars. Each gas turbine has 2 Turboden generators attached to it.

The reverse osmosis plant has a fixed cost 2.72 per 1000 gallons including maintenance. The fixed cost is simply multiplied by the number of gallons per day required to determine an overall cost for the facility.

Storage costs are variable and determined by the amount of storage deemed necessary. An average hydrogen storage cost of $0.07 per cubic foot of hydrogen and $1.00 per gallon of water can be used to derive costs.

The cost of the electrolysers is dependent based on the demand for hydrogen production. The National renewable energy lab report from September 2009 estimated that a cost of $800 per kilogram per day for hydrogen production. In our modeling we have doubled this to $1600 per kilogram to represent that the electrolysers are not active full time.

The balance of plant costs includes yard piping, the control room including associated hardware and software, and facility buildings. The yard piping is site specific but an estimated 150 dollars per lineal foot can be assumed which includes pumps and valves. The control room will consist of a computer system to monitor and control plant operations. This system including software is roughly estimated to cost 2.5 million dollars. The facility buildings are estimated to cost $150 per square foot which includes all internal machinery and piping.

Three separate economic models describe the potential income of the plant. The first is a model where the end user and grid prices differ. In this model the end user receives a price break on the demanded continuous power; all other excess power is sold to the grid at a constant rate. The second model has no distinction between grid price and end user price. This model can also be represented as a strait sale to the grid. The last model type is a stand-alone type where no excess power generated by the solar field is sold. This model represents no grid connectivity and a fixed continuous demand.

Economic Case Studies:

Three of the four studies have the following in common:

Location

Overall continuous power demand

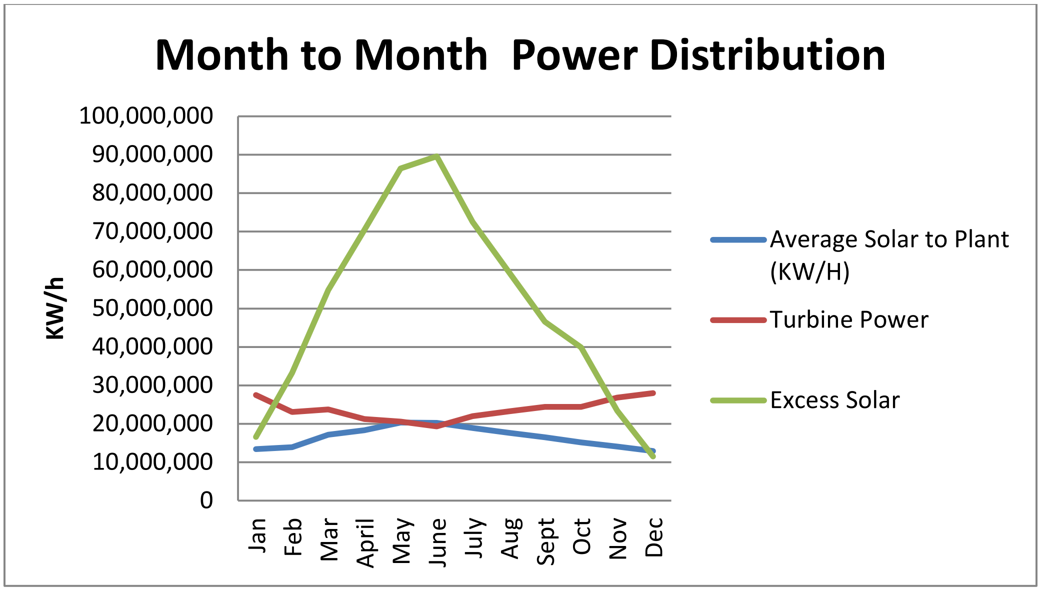
Solar field size

Plant equipment

Hydrogen Demand

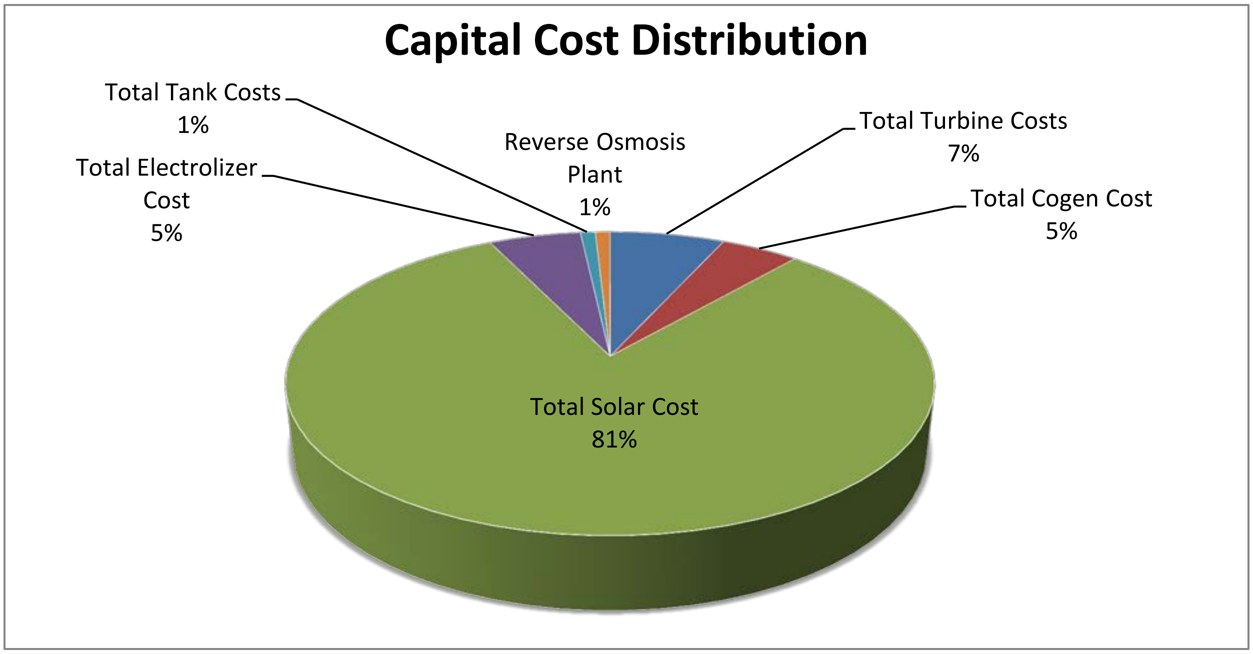
Storage field size

The only differences between the first three studies are the method and price of sales, all capital costs remain constant. All models assume a continuous power demand of 55 MW, with a solar field size of 450 MW. Each model also uses weather conditions from El Paso, Texas as reported by NOAA. Due to El Paso's weather and location much more solar energy is produced during the summer. This decreases total turbine demand noticeable in those months. The following graph shows power generation potential.



Increases in solar field productivity lower turbine power requirements while increasing solar contributions to "stated plant output"

Total capital costs for all models are 1.494 billion dollars. The following chart shows capital cost break downs for all models.

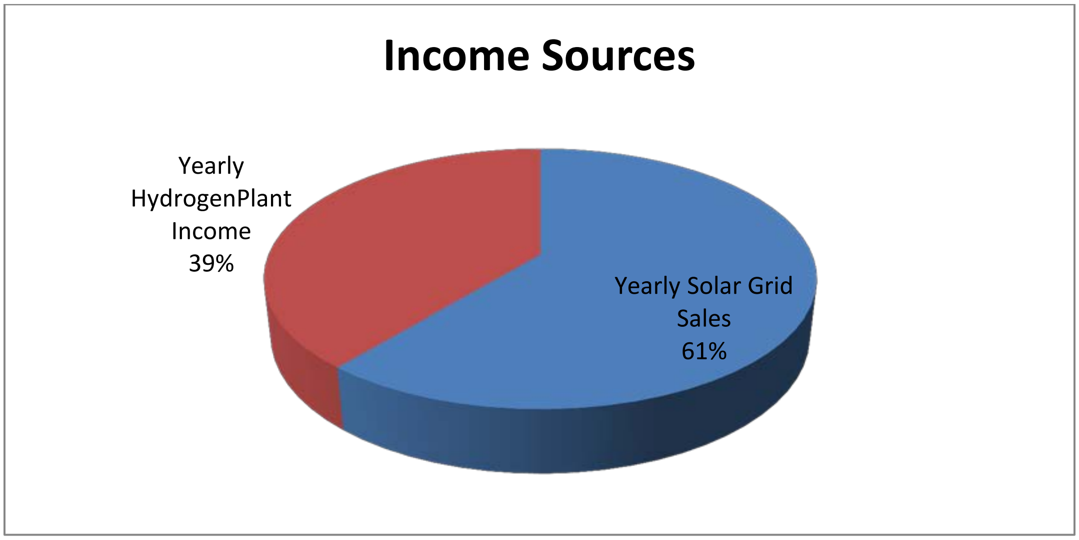


Item costs as a percentage of total capital cost. All costs less than 0.5% are not shown

We project out lifetime maintenance costs of just over 100 million dollars brining the lifetime plant cost to 1.597 billion dollars.

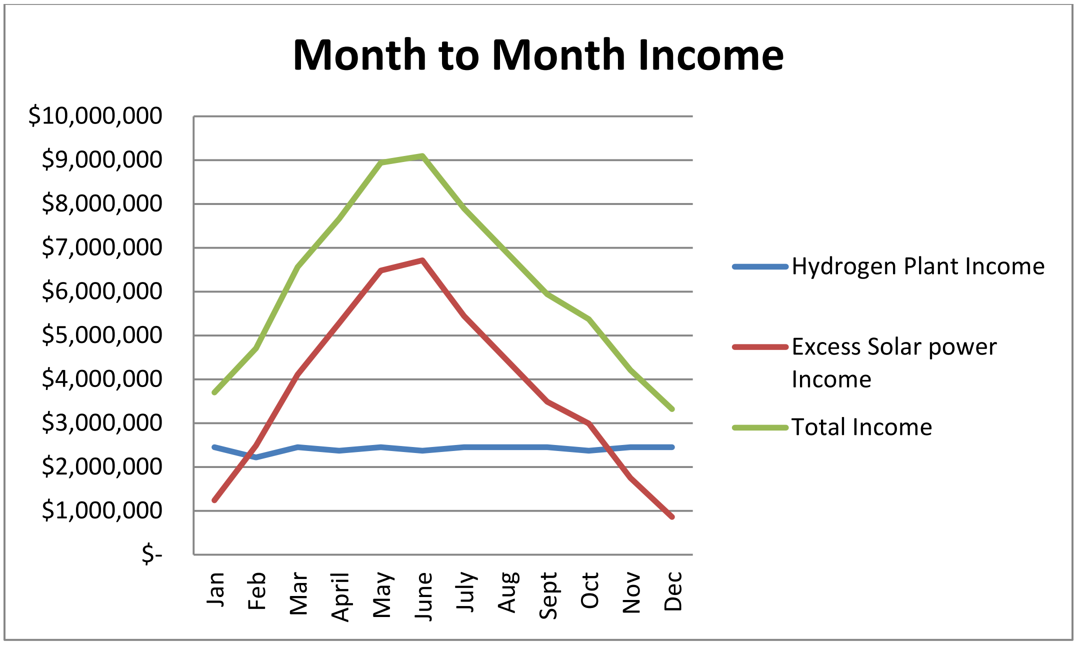
Model 1: End User with Grid

The first model sells power to an end user at the rate of $0.06 per KWh and any excess power is sold to the grid at a rate of $0.075. In this model 604,000 MW of excess solar are sold to the grid in an average year, while 482,000 MW are sold to the end user. This results in $45,334,180 a year in excess solar sales and $28,908,000 a year from hydrogen plant sales.



Total income as a percent

The income is not distributed evenly over the year as the majority of excess solar sales come from May to August. The following graph shows income distribution month to month in an average year.



Income varies month to month as solar production increases and decreases throughout the year.

After 30 years of expected plant life a total project income of 2.227 billion dollars is projected. This will yield a projected net profit of $629,296,000 or a 39.3% return on the initial investment.

The plant produces a total of 35.58 million megawatts over its lifespan with a total cost of 1.597 billion dollars this yields a $0.0490 cost per KW well within conventional generating costs.

Model 2: Grid only

The second model assumes that a local utility is buying all power produced at one fixed rate. In this model the power produced from the hydrogen plant as well as any excess solar power from the field is sold at a constant $0.075 per KWh. The amount of power generated by the plant and the solar field remain the same as the size of both remains unchanged. A total of 32,587,672 MW are produced over the plant life yielding a total income of 2.44 billion dollars. As with model 1 profits are not evenly distrusted over the course of a year following the same pattern as Model 1. Price per KWh also remains constant with Model 1 at $0.049 per KWh

Model 2 is slightly more profitable than model one due to the increased 0.015 increase in sales from the energy produced in the hydrogen plant. Models 2 yield a projected total profit of $846,106,000 or a 52% return on initial investment.

Model 3: International Pricing

Model 3 is a variation on Model 2, the only difference is the sale price of the power. It is designed to reflect an international sales rate. Energy rates outside of the United States vary from $0.20 to $0.50. We estimated a conservative sale cost of $0.15 per kw in this model. All other factors including the weather for El Paso, Texas remain the same. As with Models 1 and 2 income varies from month to month at the rate described in Model 1.

Total projected income per year is $162,938,000. Approximately 90 million is from excess solar production, while 72 million is from hydrogen plant production. A lifetime 3.29 billion dollars in total revenues is expected over the 30 year plant life. This is a 220% return on investment.

Model 4: Stand-alone

The standalone model differs from the other 3 models in that the solar field has been sized to the absolute minimum required to provide enough hydrogen production for the shortest "average solar day" In this case 401 MW versus the 450 the other models had. Without excess solar power sell back efficiency must be maximized and capital costs reduced as much as possible. This model is only suited for area with no grid connectivity and assumes no excess power will be bought during daylight hours. It is entirely possible that depending on site locations that some excess power maybe sold however it is impossible to model without a detailed use analysis report.

The total cost for the plant comes in at 1.363 billion dollars as opposed to 1.597 billion dollars for all other case studies. This is a total of a 14.6% savings and brings the standalone cost down to $0.1009 per KWh. Sale price for the model is set at $0.125 which yields a total income of 1.806 billion dollars and a projected profit of 348 million dollars.