

Economic Evaluation of Renewable Energy Applications for Eastern Shore Communities of Maryland

Jeffrey M Molavi¹, Drew L Barrall²

Associate Professor, Department of Technology, University of Maryland, Eastern Shore¹

Honour's Student, Department of Technology, University of Maryland, Eastern Shore²

ABSTRACT:With growing concerns about the future and security of the world's energy supply, various renewable energy technologies have been used thorough the millennium. Renewable energyproduction for the generation of electricity is very appropriate and rather practical for development particularly in rural areas.Finding alternative sources of electrical energy that are both economical and environmentally sustainable is pivotal for improving the quality of life in communities. Photovoltaic—the direct conversion of solar energy into electricity—has a history of about 50 years. This field of study and the resulting industry have been rapidly growing and improving and are expected to become a significant part of the world's energy future. Additionally, the use of solar energy over the recent years has increased dramatically especially in rural areas. This paper will focus on providinga guideline to help utility companies in area who may consider investing in an appropriate renewable electricity generation project and for the responsible agencies to support such investment.Evaluationof renewable energy in general and photovoltaic in particular to produce electricity in the Eastern Shore of Maryland is undertaken in this study.

KEYWORDS:Renewable Energy, Wind Turbine, Photovoltaic Panels. Energy costs, Electricity

I. INTRODUCTION

In modern societies, a critical resource necessary to daily life is electricity. Electricity is required to perform many of the functions of a building, including lighting, heating and cooling, computer systems, appliances, and equipment. It is also necessary for industrial and utility processes that society needs to operate. Electricity is a scarce resource because of the methods used to generate electrical power. From the 19th century when electricity was first commonly used for human technology until recently, electricity was generated almost exclusively by fossil fuel combustion. In 2012, two thirds of the world's power was still created by these methods [1]. The problems with this type of power generation are a serious issue for the world's future. Coal, gas, and oil are nonrenewable resources, meaning there is a limited supply available on the earth. Eventually, there will be none of these resources left to generate electricity or to perform other functions such as material manufacturing. Also, fossil fuel power plants are one of the biggest contributors to pollution on this earth. Pollutants from power generation include carbon dioxide, which is responsible for global warming; as well as sulfur dioxide and nitrogen oxide, which contribute to smog and acid rain. There is a difference between the major fossil fuels used with respect to the amount of pollution created. Coal has been the largest source of electrical power throughout history and it remains that way in many countries. Natural gas is the second most common fossil fuel for power generation, and it emits greenhouse gasses at about half the rate of coal. In some countries, fuel oil is used for power generation, but this is not a significant improvement over coal with respect to pollution [2]. Therefore, natural gas is the preferred fossil fuel both for heat and power generation. Using natural gas is a step in the right direction in order to begin to phase out coal as the primary fossil fuel. However, all fossil fuels are scarce and contribute to high rates of pollution. Therefore, alternative power generation methods are necessary to replace fossil fuel combustion for power generation.

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II. BACKGROUND INFORMATION

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable fuels are not a new phenomenon; although they may seem so because of the global debates as a solution to the world's energy problem during last few decades. The clean energy industry generates hundreds of billions in economic activity, and is expected to continue to grow rapidly in the coming years. There is tremendous economic opportunity for the countries that invent, manufacture and export clean energy technologies.

1. Nuclear Power

One controversial solution to this problem has been nuclear power, which was introduced in the 1950s. This type of energy is created in power plants from nuclear fission of the uranium atom in a reactor. The generated heat is used to produce steam that drives massive turbines that generate electricity. Although nuclear energy has declined in its proportion of the worldwide electricity supply since 2000, it was still responsible for over ten percent of the supply in 2012 [1]. Nuclear power is an improvement over fossil fuels because it does not consume critical nonrenewable resources and it does not emit high levels of pollutants [2]. However, there are a lot of concerns whenever nuclear processes are used on this earth. Nuclear warfare has created vast fear across the world, which began when atomic bombs were used to kill thousands of civilians during World War II. It is assumed that several nations are keeping many nuclear weapons, any one of which could destroy the entire planet Earth. This is why many people are opposed to nuclear energy being used for any means. The environmental impacts of nuclear energy produced in an enclosed environment are still not certain, but there is evidence that damage is being done. When an accident happens and there is an explosion at a nuclear power plant, the affects are catastrophic on the nearby area due to the release of radioactive material. This is not to say that traditional power plants are not dangerous, but the element of the unknown makes nuclear power use highly debated. For these reasons, nuclear energy is not the ultimate answer for the future of power generation. The necessary solution is energy producing methods that are renewable and cannot damage the environment.

2. Hydroelectricity

Renewable electricity generation uses natural energy from the earth to produce electricity for human consumption. The oldest and most widely used method for renewable electricity is hydroelectric power, which uses the force of falling water to produce electricity. Hydroelectric power plants began being used commonly around the turn of the 20th century in the United States. As of 2012, 6.9% of the electricity in the world and 16.5% in the United States was generated by hydroelectric plants, and the amount of power supplied will continue increase in coming years [1]. It is an economic advantage to use these plants because the cost of operation is lower than fuel plants [3]. Also, this type of power generation releases minimal greenhouse gasses, so it is beneficial to the atmosphere [2]. However, this system does have its drawbacks due to the scarcity of water. Only certain areas of the world have access to the water necessary to operate hydroelectric power plants because these are the areas located near large bodies of water. Some plants use natural waterfalls, but in most cases natural waterfalls must be built including the construction of large dams. This disrupts the natural flow of the earth's water; it's most precious and vital resource. In the areas where hydroelectric plants are constructed and in downstream locations, the natural land can undergo a massive transformation. Changing the earth's environment in this way can destroy ecosystems and alter bodies of water, to the detriment of the people and animals that rely on them. Also, high construction costs for these massive projects can deter their development unless confidence of proper operation is high. Hydroelectricity has been the main competitor to fossil fuel combustion for power generation all along, but it retains only a fraction of the total energy supply due to the limitations of the system. Hydroelectric plants will always have their place in electrical generation because they produce a substantial fraction of the world's power and they use renewable energy. However, other renewable electrical generation methods are necessary to provide the rest of the power demand.

3. Wind Energy

The natural energy of the earth's wind is another legitimate renewable resource for electrical power generation. Windmill technology has been in society dating back to ancient civilizations, and from this wind turbines were conceived. The first wind turbine electricity generation stations appeared around the turn of the 20th century, and their popularity has increased dramatically since 2000. From 2009 to 2012, the worldwide percentage of electricity supplied

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by wind energy increased from 1.3% to 3.3% [1]. Wind farms, large groups of wind turbines operating together, are now able to supply power to cities. The reason wind turbines have become so much more popular is the economic advantage of their use. Wind is a free resource and the power generation is driven by a natural process, as opposed to power plants that are expensive to operate. Over a fraction of the life of a wind turbine, the savings from not operating a plant as a supplier or paying for electricity from a utility provider as a consumer will pay for the cost of the turbine. With growing popularity, wind turbines have become much less expensive and more attractive as an investment. There are many different styles, configurations, and sizes for wind turbines; so the choice of a particular turbine entails significant design concerns [7]. The main drawback to using wind turbines is that it is only effective in regions with high sustained winds. Another concern is that wind turbine power is only partially efficient, and turbines can lose more efficiency if not well maintained.

4. *Solar Energy*

The best natural source of energy for the Earth comes from the very object that makes life possible, the sun. Everyone feels the power of the sun to provide heat and light to our world, but sunlight can also be harnessed to produce electrical power. There are two basic methods for using solar energy to create electricity; concentrated solar power and photovoltaic panels. Concentrated solar power systems use mirrors and lenses to reflect sunlight onto a small area, where it is converted to heat that powers a steam turbine. The original concentrated solar power stations in the United States were built in the 1980s, but since 2010 many more stations have been built [8]. This type of solar station is gaining popularity as costs decrease, and applications are very practical for developing countries. The other more popular type of solar energy system is the photovoltaic panel, which has been used for large power plants since the 1980s in the United States. The electrical power created by photovoltaic systems had increased tenfold within the last ten years, and photovoltaic panels are now a legitimate option for renewable power generation [9]. The dramatic rise in popularity is due to the increasing efficiency of the photovoltaic cells and decreasing system cost. Photovoltaic panels can be used to create small amounts of power for residences and small business buildings, or they can form massive arrays that can provide power to entire towns. Photovoltaic cells use crystalline silicon to convert sunlight to direct current power, which is converted to alternating current power with an inverter. The main variable controlling the amount of electricity a solar energy system can produce is the amount of sunlight that reaches it. This differs depending on the season, geographic location, and weather. Climates closer to the equator and with more sunny days will produce more power and will be more profitable. However, solar energy systems are proving their worth as they increase in popularity throughout the world.

5. *Other Renewable Energy Systems*

The reason that the other renewable electrical power generation systems are not as popular as hydroelectricity is because they require advanced technology or their effective application is even more limited. Systems that use developing technology are always more expensive when they first become popular, which is the current status of renewable energy harvesting. System efficiency increases as technology improves and costs of installation are reduced as manufacturers become more experienced. It is because of the high installation costs that renewable energy is often overlooked; however it is becoming a more viable option. The operation of natural electrical generation is typically more efficient than that of traditional plants, which offers a significant economic benefit that ultimately overcomes the high initial cost. One example of method of renewable power generation that is still in the development stages is tidal power. Tidal power generation relies on the natural movement of the Earth's waters to harvest energy. This remains a rare method to produce power because of the high expense of this system, although prices are becoming more reasonable [4]. Geothermal energy is most commonly associated with heat pump systems, but it can be used to directly generate electricity as well. Geothermal power stations use steam directly from the earth or produce steam from hot liquids within the earth's crust to drive turbines. In either case, heat from deep within the earth is renewable because the earth maintains constant heat.

The Geothermal power stations contribute relatively little to pollution compared with traditional plants, but they can contribute to soil problems and therefore can be risky [2]. The costs are extremely high to build a geothermal power station, which includes extensive earthwork and testing [5]. For these reasons, applications of geothermal electricity generation remain very limited, accounting for less than half a percent of energy use in both the United States and China [6]. Another sustainable energy source that can be used for power is biomass, which is organic plant material. The most commonly used biomass throughout history is wood, but other plants and forest material can be used for

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burning. Producing power by burning organic material produces pollution similar to fossil fuels, but the fuel sources are renewable and much easier to harvest. 1.8% of the world’s electricity in 2012 was produced by burning biomass or waste [1]. The more common application of biomass is to create biofuels that are used as fuel additives, such as ethanol. In either case, development of biomass technology is important for the future as oil supplies diminish and coal is phased out as the primary fossil fuel.

III. VARIATIONS IN ELECTRICITY SOURCES

The proportion of electricity generated from different sources has changed shape within the past two decades, and it varies dramatically from country to country. The following tables, derived from information published by the International Energy Agency, show percentages of electricity production by source [1]. Table 1 shows percentages for the energy sources of world power generation from 1990 to 2012, and Table 2 shows the same for the United States. The proportion of electricity generated from fossil fuels has remained at about two thirds, but natural gas use is increasing while coal and oil use is decreasing. The United States uses more oil than the world average, and the percentage of electricity from burning oil decreased six percent since 1990. This was accompanied by a more modest gain of 7.6% for natural gas compared to 17.6% for the world. The use of coal actually increased 3% in the United States, while nuclear energy decreased from 17% to 10.8%. The decline in nuclear power in the United States shows that it is losing popularity and new plants are not being built, however nuclear energy has maintained a constant proportion of production worldwide. Hydroelectric power accounts for a larger share of the total power in the United States than worldwide, where the percentage declined from 9% to 6.9% from 1990 to 2012. Hydroelectric plants are an excellent source of power and will continue to operate into the future, and the decline may be accounted for by the huge increase in natural gas plants. Power suppliers across the world have been concentrating more on increasing the use of natural gas and decreasing the use of coal. This is an example of the gradual shift towards more renewable and less polluting energy production.

The use of biofuels and waste is gaining popularity in the United States, while remaining constant throughout the world. Wind and solar energy were responsible for less than a tenth of a percent of electricity production in 1990, but within the last few years the use of these systems began increasing rapidly compared to other methods. Table 3 shows the percentage of electricity generated by source in 2012 for the eight countries that produce the most electricity. In most countries, fossil fuel combustion is still the most productive source of electricity, although the fuel used varies greatly. China and India both use coal for over 70% of their electrical generation; while Russia, Canada, and France rely on coal for less than 16% of electricity. Japan instead has a high proportion of electricity from natural gas and oil, at 38.4% and 17.5% respectively; while Germany used natural gas for nearly half of its power. France produced 75.4% of its electricity in 2012 from nuclear plants; while China, India, and Japan all produced less than 3%. Hydroelectric power is most productive in Canada by far, where 60% of all electricity was generated from hydroelectric plants. The remaining renewable energy sources are still only used for a small percentage of power worldwide, but accounted for over 2% of production in all these countries but Russia. Germany is the most reliant on these new systems, using by far the highest proportion of biofuels and waste, wind energy, and solar energy in 2012.

Table 1: World Electricity Production by Source

Year	Coal	Oil	Natural Gas	Nuclear	Hydro	Biofuels/Waste	Wind	Solar
1990	52.8%	4.1%	11.9%	19.0%	9.0%	2.7%	<.1%	<.1%
1995	51.2%	2.4%	14.8%	19.9%	9.4%	1.8%	.1%	<.1%
2000	52.5%	2.9%	15.6%	19.7%	6.9%	1.8%	.1%	<.1%
2005	50.2%	3.3%	18.2%	18.9%	6.9%	1.7%	.4%	<.1%
2009	48.8%	1.3%	20.8%	19.2%	6.5%	1.6%	1.3%	<.1%
2012	38.3%	.8%	29.5%	18.7%	6.9%	1.8%	3.3%	.2%

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Table 2: United States Electricity Production by Source

Year	Coal	Oil	Natural Gas	Nuclear	Hydro	Biofuels/Waste	Wind	Solar
1990	37.3%	11.0%	14.8%	17.0%	18.5%	1.1%	<.1%	<.1%
1995	37.5%	9.2%	15.2%	17.5%	19.1%	1.0%	.1%	<.1%
2000	38.7%	7.8%	17.8%	16.7%	17.4%	1.1%	.2%	<.1%
2005	39.9%	6.2%	20.2%	15.1%	16.4%	1.3%	.6%	<.1%
2009	40.1%	4.8%	21.8%	13.3%	16.5%	1.6%	1.4%	.1%
2012	40.3%	5.0%	22.4%	10.8%	16.5%	1.9%	2.3%	.4%

Table 3: 2012 Electricity Productions by Source for Top Producing Countries

Country	Coal	Oil	Natural Gas	Nuclear	Hydro	Biofuels/Waste	Wind	Solar
China	75.8%	.1%	1.7%	1.9%	17.5%	.9%	1.9%	.1%
USA	40.3%	5.0%	22.4%	10.8%	16.5%	1.9%	2.3%	.4%
India	71.0%	2.0%	8.3%	2.9%	11.2%	1.9%	2.5%	.2%
Japan	29.3%	17.5%	38.4%	1.5%	8.1%	3.8%	.5%	.7%
Russia	15.8%	2.6%	49.0%	16.6%	15.6%	.3%	0%	0%
Germany	45.6%	1.2%	12.4%	15.7%	4.4%	8.1%	8.1%	4.1%
Canada	10.1%	1.1%	10.6%	15.0%	60.0%	1.4%	1.7%	.1%
France	3.9%	.8%	3.9%	75.4%	11.3%	1.3%	2.7%	.7%
World	38.3%	.8%	29.5%	18.7%	6.9%	1.8%	3.3%	.2%

IV. COMPARISON OF RENEWABLE ENERGY SYSTEMS

The preceding sections offer an overview of the different types of electricity generation. Creating a new power plant is a massive undertaking with many different consequences. The most important factor to the plant owner is economics, while the factor most significant to society is environmental sustainability. Power plants that use fossil fuel combustion have been the primary source of electricity throughout the brief history of human electrical service, but they are responsible for a large part of the pollution problem our world now faces. Additionally, the limited supplies of such fossil fuels as coal and natural gas are being depleted rapidly. This creates a real need for alternative energy production. Nuclear power is an improvement over fossil fuel power because it does not normally pollute the environment. This method is not the ultimate answer to the problem because it uses the natural resource of uranium, and it creates a lot of controversy due to the radiation and disaster potential of nuclear processes. The real solution to the world's power demand is renewable energy, which does not create much pollution and uses natural energy to generate electricity. As technology for harnessing these energy sources improves, renewable energy systems become more efficient and less costly to the supplier. An increase in the portion of electricity supplied by sustainable systems can reduce electricity costs for the consumer and contribute to a cleaner environment. When making a proposal for a new power plant, there are many factors that determine the best option. The first concern is the desired electrical output, which will determine the size of the plant necessary to provide it. The long term economic benefits of a proposed plant depend most on the efficiency of the system it uses. The regional considerations that vary depending on location are the price and availability of competing systems, prevailing energy costs, and geographic features and climate.

V. EASTERN SHORE, MARYLAND

The authors are from the University of Maryland Eastern Shore, a four year historically black college located in the small town of Princess Anne, Maryland. This area is part of the region of Maryland known as the eastern shore, which includes the nine counties east of the Chesapeake Bay. This side of Maryland is part of the Delmarva Peninsula, which also includes the state of Delaware and one county in Virginia. The economy of Delmarva is based largely on agriculture, seafood, and poultry. This region is mostly rural area with very few large cities outside of northern

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Delaware. The largest urban area in the Eastern Shore of Maryland is the city of Salisbury, with a population of about 30,000 in 2010 [10]. Because it has the most electrical consumption in the region, we will focus on Salisbury as the location for a new power plant. Salisbury is an established urban area with existing infrastructure including the power grid. Since there is not a need for new power, the size of a supplementary power plant is only constrained by the amount of financial resources the supplier can invest. The typical production of a large power plant is at least one gigawatt-hour per year, which will be the target output of the proposed plant. There are rural areas just outside the city limits, which will provide a site for the plant. The Delmarva Peninsula is located on the Atlantic coastal plain and has a humid subtropical climate. The summers are hot and humid, while the winters are cool to mild with occasional bitter cold. Salisbury has an average January low of 29.8 ° F and average July high of 87.4 ° F, and the average annual precipitation is 45.9 inches with 9.9 inches of snowfall [11]. The climate characteristics are important to determine the estimated efficiency of sustainable energy systems.

VI. SYSTEM SELECTION

One distinct advantage of sustainable energy power generation is that a plant does not need to be very large to be effective. The costs of operating traditional plants that use fossil fuel combustion or nuclear reaction are extremely high. These plants must be very large and supply a large amount of power to be economically profitable for the supplier. The size flexibility that a sustainable power plant provides makes it the obvious choice for this proposal, in addition to the other reasons previously discussed. Hydroelectric power plants are the most common type of sustainable energy generation, but similarly they need to be large to maximize their benefit. These plants also require a large natural water supply only available at coastlines, but our system needs to be located as close as possible to the existing power grid. For these reasons our plant proposal will not use hydroelectric power. Uncommon sustainable systems such as geothermal power generation are too expensive and require too many installation expenses to be practical for this proposal. When biomass or biofuels are used, complicated plant processes come into play again and there are significant operating expenses. What we need for our electrical generation is a system that stands above ground on solid land that can operate without assigned employees. Therefore the choice for our sustainable energy system is between solar energy and wind energy. In order to determine whether to use solar energy or wind energy, we must simply determine the cost of each system with the same power capacity per year. A preliminary investigation into each system will provide a general idea of which system is more expensive. The initial cost and yearly costs will be used to find a life cycle expense for each over an estimated life of 20 years.

VII. WIND ENERGY SYSTEM COST

To determine the annual energy output of a wind turbine, the needed information is the rotor diameter and the average wind speed at the center of the turbine. A typical 1.5 MW land based turbine has a hub height of 65 meters or about 213.3 feet and a rotor diameter of 70 meters or about 229.7 feet [12]. A publication by the National Climatic Data Center in November 1998 lists the average wind speeds for various locations throughout the United States. The closest location to the eastern shore listed is the Patuxent River Naval Air Station, and its annual average wind speed is computed from the monthly averages as 7.25 miles per hour [13]. The standard height for measuring wind speeds is 10 meters or about 32.8 feet [14]. To calculate the equivalent wind speed at the hub height of the turbine, the wind profile power law is used: $u/u_r = (z/z_r)^\alpha$. In this formula, u is the wind speed at height z , u_r is the wind speed at reference height z_r , and α is approximately 1/7 for neutral stability conditions such as at the proposed site [15]. Using the formula, the equivalent wind speed for the turbine is about 9.57 miles per hour. The annual energy output in kilowatt-hours using this information can be found from the equation $AEO = 0.01328 D^2 V^3$, where D is the rotor diameter in feet and V is the average annual wind speed in miles per hour [16]. For the proposed turbine and location, the annual energy output is 614,124 kilowatt-hours, or .614 gigawatt-hours. In order to reach the target of one gigawatt hour, two turbines are necessary producing 1.228 gigawatt-hours per year. A December 2006 publication by the National Renewable Energy Laboratory lists a cost estimate for the 1.5 MW turbine mentioned above in 2002 US dollars. The initial capital cost is listed at \$1,403,000 per turbine for a total of \$2,806,000. The replacement part cost is listed as \$16,000 per year per turbine and the operation and maintenance is listed as \$30,000 per year per turbine [12]. This totals to \$1,840,000 for two turbines for twenty years, for a grand total of \$4,646,000 in 2002 dollars. The 2014 price is about \$6,147,000, accounting for a cumulative rate of inflation of 32.3% [17]. There is no deduction for salvage value because this is offset by the decommissioning costs of wind turbines [18].

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VIII. SOLAR ENERGY SYSTEM COST

Two 1.5 MW wind turbines can produce 1.228 gigawatt-hours per year, so the equivalent amount of solar panels to produce the same power must be found. A 2010 textbook by Joseph Wujek and Frank Dagostino lists the area of solar panels necessary to produce one kilowatt-hour per day based on system efficiency and location. The closest location to Salisbury listed is Silver Hill, Maryland where 15 square feet of panels are necessary to produce one kilowatt-hour per day at 16% efficiency [19]. Using this value, the area of solar panels necessary to provide 1.228 gigawatt-hours per year is 50,466 square feet. A solar panel model that meets the requirement of 16% efficiency is the Suniva OPT260-60-4-100-H 260 Watt Mono Solar Panel. This panel contains 60 cells per module and has dimensions of 65.08 inches by 38.66 inches, for an area of 17.47 square feet [20]. 2,889 of these modules are required to cover 50,466 square feet. The price listed on the Gigawatt, Inc. web site for this panel model is \$289.42 per module. The equipment needed to bring the system into operation in addition to the panels amounts to two thirds of the panel cost, and the labor cost amounts to half the panel cost [21]. Accounting for this, the total cost is about \$627 per module, for a total initial cost of \$1,811,624. A 2007 publication *Photovoltaic Systems* by American Technical Publishers, Inc. provides an example of life-cycle costs for a photovoltaic system with a life of 20 years. For a 5 kilowatt system with an initial cost of \$30,000; the annual inspection cost is \$1,359, the lifetime replacement costs are \$4,135, and the salvage value is \$2,280 [22]. This amounts to a total life cycle cost of \$33,214 for a factor of about 1.104 compared to the initial cost. If this factor is applied to the price of the solar panels, the total life cycle cost for the proposed solar plant is about \$2,000,000. Comparing this price to the price for the wind turbines shows that the solar system is clearly a better option.

IX. INVESTMENT ANALYSIS FOR SOLAR FARM

The photovoltaic system life-cycle cost analysis just mentioned lists an inspection cost of \$100 per year for a 5 kW array, with a \$2,000 inverter replacement after ten years and \$2,200 battery bank and module replacements after eight and sixteen years. Converting these values to 2014 dollars yields inspection costs of about \$115, an inverter replacement cost of about \$2,300, and battery bank and module replacements costing about \$2,525 [17]. The OPT260-60-4-100-H 260 Watt Mono Solar Panel offers a 25 year warranty, so the practical life of the solar farm can be increased to 25 years [20]. Of course, there will need to be another inverter replacement after 20 years and an additional replacement of battery banks and modules after 24 years. If 3,000 260 watt modules are used, the total power of the system is 780 kilowatts. If we assume due to economy of scale that the initial cost of a large amount of solar panels is about 90% of the cost for a small project, the cost per module can be reduced from \$627 to about \$564 per module, for a total initial cost is \$1,692,000. If a 5 kilowatt system has inspection fees of \$115 per year, a 780 kilowatt system would have fees of \$17,940 per year. Similarly, the inverter replacements would cost \$358,800 and the battery and module replacements would cost \$393,900. If the salvage value after 20 years is one sixth of the purchase price, it may be 2/15 of the purchase price after 25 years, which would amount to \$225,600. For the owner of the solar farm, the revenues from the sale of electricity will eventually cover the expenses. 3,000 modules will cover 52,410 square feet and produce 1.275 gigawatt-hours per year. In August 2014, the average price of electricity in Maryland was 11.97 cents per kilowatt-hour [23]. The revenue from electricity sales will be \$152,655 per year at this cost.

X. RESULTS

All the expense costs must be changed to their present value by using the discount rate of .04 [22]. The annual revenue from electricity sales will remain constant because the electricity price should rise with an inflation rate that equals the discount rate. The breakdown of the expenses and revenues for this proposed solar plant are shown in a table below, and the cumulative income over time is also shown in Figure 1. After 18 years, the revenues from power production of the solar farm overcome the expenses. At the end of the life of the farm, the cumulative income is \$880,832. This works out to a profit per watt capacity of \$1.13 per watt and profit per kilowatt-hour of \$.69. The solar farm is a worthwhile investment for the supplier although it takes 18 years for the investment to produce a profit. The majority of the expenses are attributed to the initial cost of the plant construction including the cost of the solar modules, the inverters, and battery storage; as well as the equipment needed to connect to power distribution and labor for installation. The profits from the sale of electricity are high enough at the standard rate to pay for all of these expenses

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as well as the periodic repair and inspection costs. Solar power cogeneration requires very little maintenance and provides the most reliable power generation device.

Table 4: Life Cycle Costs for Proposed Solar Farm

Year	Expense	Type	Inspection Expense	Revenue	Income	Cumulative Income
0	-\$1,692,000	Initial			-\$1,692,000	-\$1,692,000
1			-\$17,250	\$152,655	\$135,405	-\$1,556,595
2			-\$16,587	\$152,655	\$136,068	-\$1,410,527
3			-\$15,949	\$152,655	\$136,706	-\$1,273,821
4			-\$15,335	\$152,655	\$137,320	-\$1,136,501
5			-\$14,745	\$152,655	\$137,910	-\$998,591
6			-\$14,148	\$152,655	\$138,507	-\$860,084
7			-\$13,633	\$152,655	\$139,022	-\$721,062
8	-\$287,819	Battery/Module Replacement	-\$13,109	\$152,655	-\$148,273	-\$869,335
9			-\$12,604	\$152,655	\$140,051	-\$729,284
10	-\$242,392	Inverter Replacement	-\$12,120	\$152,655	-\$101,857	-\$831,141
11			-\$11,653	\$152,655	\$141,002	-\$690,139
12			-\$11,205	\$152,655	\$141,450	-\$548,689
13			-\$10,774	\$152,655	\$141,881	-\$406,808
14			-\$10,360	\$152,655	\$142,295	-\$264,513
15			-\$9,961	\$152,655	\$142,694	-\$121,819
16	-\$210,306	Battery/Module Replacement	-\$9,578	\$152,655	-\$67,229	-\$189,048
17			-\$9,210	\$152,655	\$143,445	-\$45,603
18			-\$8,856	\$152,655	\$143,799	\$98,196
19			-\$8,515	\$152,655	\$144,140	\$242,336
20	-\$163,752	Inverter Replacement	-\$8,188	\$152,655	-\$19,285	\$223,051
21			-\$7,873	\$152,655	\$144,782	\$367,833
22			-\$7,570	\$152,655	\$145,085	\$512,918
23			-\$7,279	\$152,655	\$145,376	\$658,294
24	-\$153,669	Battery/Module Replacement	-\$6,999	\$152,655	-\$8,013	\$650,281
25	\$84,626	Salvage Value	-\$6,730	\$152,655	\$230,551	\$880,832

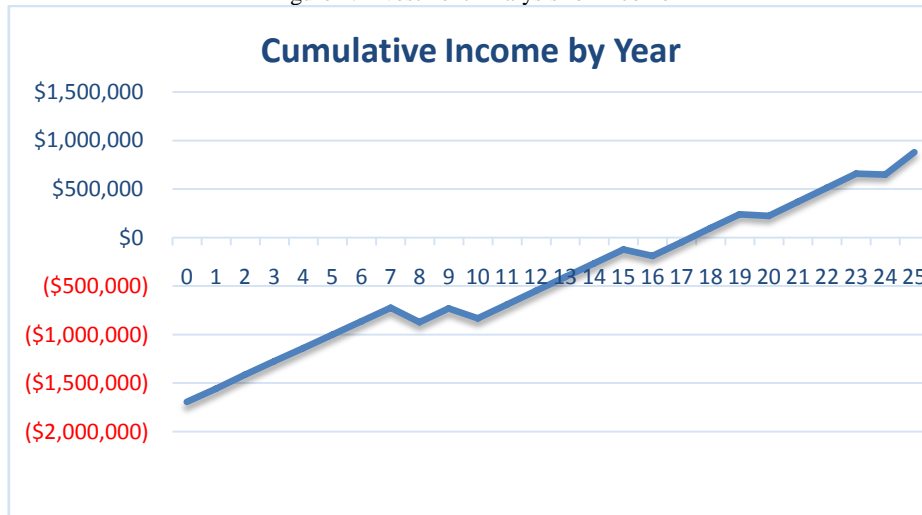
XI. CONCLUSION

Solar energy is widely available throughout the world and can contribute to reduced dependence on energy imports. Remarkable efficiency results have been achieved in the Photovoltaic systems as technology improves rapidly. PV market is also growing at the very high rate of up to 40% annually, while the cost of PV has dropped dramatically as the industry has scaled up manufacturing and incrementally improved the technology with new materials. On the other hand the installation costs have come down too with more experienced and trained installers. However, the U.S. still remains behind other nations that have stronger national policies to shift energy use from fossil fuels to solar. Globally, the U.S. is the fourth largest market for PV installations behind world leaders Germany, Japan and Spain. In this paper, we have provided the photovoltaic system life-cycle cost analysis, investment analysis, and have showed when the profit on investment is achieved.

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Figure 1. Investment Analysis for Income



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