Project Number:

Photovoltaic System Acceptability in the Future

An Interactive Qualifying Project Report
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by

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Executive Summary:

The purpose of this project was to investigate the future of photovoltaics in society. This was done by looking into many different areas of this market such as its history, government involvement, environmental effects, and the economic effects and being able to compare areas with the current methods of electricity production.

Throughout the history of photovoltaics, advances have been made to make them more desirable to the public. Increases in the efficiency have been the most significant, along with new materials that contain the photovoltaic effect. These new materials make the market larger for solar energy and therefore increase the likelihood of their implementation into society on a large scale.

Governments all around the world have been making strides to make the conversion into alternative sources of energy. Some states are making an effort to provide people with an incentive to use solar energy with the Renewable Energy Act and the Feed-In Tariff. These campaigns decrease the user's electric bill and in some cases end up giving money back to them. California is also currently in the middle of a $3 billion dollar solar program to make the state more green. Other countries such as Japan and Germany have initiated similar plans to that of California where they implement solar panels onto roofs.

The environmental effects of electricity production are very important. The amount of pollution given off directly affects the health of the public. Photovoltaics release very small amounts of pollution and can be used as a substitute for coal since fossil fuels emit a large amount of unwanted byproducts. Nuclear energy doesn't have many emissions, but they are very

dangerous if something were to go wrong with them. This leaves solar energy as a viable option, but the cost is one of the main issues with a full scale implementation.

The cost of photovoltaics is one of the main reservations that people have against purchasing them. People don't see them as practical since they only operate at 24% efficiency as of recently, and it takes too long to make their money back. This hasn't stopped solar panels from being purchased over the last few years on a domestic scale though; Figure 4 shows their sales. This trend is expected to continue as the world becomes more and more aware of the limited availability of fossil fuels. As the technology related to the efficiency of photovoltaics also increases, people will also be more prone to purchasing solar cells.

With the world making strides to become more "green", new jobs are going to occur. The World Watch Institute calculated the number of jobs needed for each major type of electricity production and their results are in Figure 5. Solar energy is estimated to need about 22% of the people needed in this market to product 1TWh/year. The total primary energy supply needed until 2030 has been projected by the IEA and solar and wind energy are to account for less than 1% of the energy used, but with a larger implementation of renewable energy sources, jobs in building plants, solar arrays, wind turbines, and the installation and maintenance of them would create a large influx of jobs.

Asthma is a growing epidemic all across the world today. Each year, billions of dollars are spent on asthma patients. This doesn't only affect their wallets, but their careers too in some cases; "Asthma is the number one cause of workforce disability…". Asthma seems to be more prevalent during times when there is heavy air pollution. The Los Angeles region has some of the worst air quality in the US and they have a population of about 10 million, meaning there is a lot of car usage. These cars emit some of the main components that have been linked to triggering asthma. When LA was compared to a Tolland county which is much smaller than LA, LA had more pollution, and more asthma attacks.

Electric Car is a potential solution for reducing the amount of emissions worldwide. Scientists are working hard to increase the range and amount of time to recharge the cars in order to make them more competitive with current cars. As they become more incorporated into society though, more charging stations will be needed which could pose a problem if everyone on the east coast for example wants to charge their car once they arrive at work. A simple solar station could be used to charge a battery while a different one is in use in the actual car, reducing the risk for blackouts.

My prediction based on the research conducted in this project is that solar energy is going to become a huge portion of our energy production over the next 20 years. Increases in technology which will lower the cost of photovoltaics and the increasing need for a substitute for fossil fuels will push society to use the sun's energy. The electric car will also become almost fully incorporated into society within 30 years. As oil become more and more expensive, people won't be able to afford the prices and have to switch to a more cost effective way to travel. Photovoltaic incorporation into society would be a large step in the energy world, and it's only a matter of time until it happens.

1 Introduction

In the developed countries around the world, almost everyone uses electricity whether to drive a car to work, or getting a can of soda out of the refrigerator. Without electricity life is extremely different than the way we have become accustomed to. In order to keep our standard of living, we need to keep electrical energy available to everyone. At some point, due to the depletion of fossil fuels, our current methods of producing electricity will become ineffective. With decreasing volumes and increasing costs of fossil fuels worldwide, and with the continuously increasing volume of resistance toward developing nuclear power, new energy sources must be devised. A new way to generate and distribute energy is critically needed. Photovoltaics, or arrays of cells containing a material that produce direct current electricity/voltage when exposed to solar radiation, should be considered!

Although the concept of photovoltaics or solar cells is not new by any means, it may provide an ideal solution to our energy production and distribution concerns for the future. So why haven't photovoltaics already become a mainstream form of energy production? This question will be investigated throughout the rest of this report and projections will be made as to the impacts of incorporating photovoltaic energy into our culture over the next several decades.

If photovoltaics were to be installed throughout the United States, the cost of implementation would clearly be the most significant factor, but as we've seen with the current methods generating electricity, the pollutants involved with the creation of processes, such as the conversion of fossil fuels to energy, is an important concern to be considered as well. Pollution leads to health related problems and those health related problems often necessitate costly treatment. Sometimes health impacts of pollution can become chronic, requiring multiple physician visits and long term medication needs throughout a person's life. Would the implementation of photovoltaics be more cost effective than the current amount of money spent on health issues connected with pollution coming from electricity production, and is there a positive correlation between implementing photovoltaics and a healthier population due to less pollution? One of the main leaders in the cause of pollution is the automobile. Millions of people each day use their cars to get them around and while doing so, emit pollution. The electric car seems like a possible solution to cutting back on the amount of pollution due to transportation, but as time progresses, and more and more electric cars are used, more and more people will need to charge their batteries when they aren't using their cars. So what would happen when everyone who drives an electric car gets home from work at 5pm and plugs their battery in to make sure it's charged up for the next morning? An excessively huge volume of energy would be drawn from the electric companies every day and would most likely result in a blackout. Different ways to attack this issue will be explored along with any relationships found between population, pollution, and health problems.

Renewable energy is something that must be considered. The negative impacts of our current practices and dwindling resources is a real problem that might not affect us immediately, but it very well could affect our children or grandchildren. The technology to use renewable energy is available; all that needs to be done is to figure out how to cut the cost of implementation. Obviously this isn't something that will happen overnight, but society should begin moving towards using it since it will help keep the earth "green" which is needed for a long term balance between the public health and its energy use. Through intensive research, a better understanding of the feasibility of photovoltaic implementation can be estimated. These projections will be made and presented at the conclusion of the investigation.

2 Background

Before an educated prediction about the future of photovoltaics can be made, some investigation should be done into the history of its evolution. This section will provide an in depth look into the discovery of photovoltaics and how it has been further developed to date. By looking at the information of the past, predictions about the potential future of this market can be made.

2.1 History of Photovoltaics

Photovoltaics have been available since the 1800's, and just like all other discoveries, it took time to be developed. This discovery occurred by chance. In 1839, the photovoltaic effect was discovered by a French Physicist named Alexandre Becquerel when he was experimenting with metal electrodes. He found that the conductance in the metal rose with illumination. In the 1870's, Willoughby Smith discovered that the same effect Becquerel found occurred using selenium. A few years later in 1876, William Adams and his student, R.E. Day observed that "illuminating a junction between platinum and selenium" [1] created the photovoltaic effect. Both the Smith and Adams' discoveries helped to pave the way for Charles Fritt, an American inventor in 1883, who described the first use of the photovoltaic effect: solar cells made from selenium wafers. In 1904, Albert Einstein published a paper that theoretically described how the photovoltaic process worked. All of his explanations were confirmed through experimentation by a man named Robert Millikan in 1916 [1]. And in 1921, Albert Einstein won the Nobel Prize for his work.

The 1950's were a breakthrough decade for photovoltaics. AT&T did several demonstrations with solar cells that ran at a 4.5% efficiency in 1954 and soon after was able to be increased to 6%. This was no match for the increases in efficiency at Hoffman Electronics though. They were able to increase the efficiency by 1% each year from 1957 until 1959, starting at 8% and ending at 10%. In 1960, Hoffman Electronics jumped their efficiency to 14%, clearly leading the way in efficiency rates for photovoltaics.

Photovoltaic incorporation into the newly developing space program around that time was also a large step for solar energy. Vanguard I, a satellite launched in 1958, was the first time solar cells were used in outer space. The cells that were put on Vanguard I were able to power the whole system. A few years later in 1966, the Orbiting Astronomical Observatory launched by NASA, orbited the Earth with a 1 Kilowatt PV array [1].

Domestic use for photovoltaics also became an area of interest with regards to solar energy. Delaware University created the first system of photovoltaics that was developed for domestic application in 1973. A few years later in 1977, NASA Lewis Research Center set up a 3.5 kW system that was able to power an entire village on an American Indian Reserve. This village consisted of 15 houses and a pumping station for the inhabitants. The Solar Energy Research Institute was also opened in Golden, Colorado the same year. In 1985, a 20% efficiency solar cell was created at the University of New South Wales in Australia.

Within the last 20 years, countries around the world have been making strong moves towards implementing solar energy on a large scale basis. Germany is leading the way with 5 of the 10 largest photovoltaic power plants in the world [2]. In 1990, Germany launched the 100,000 Solar Roofs program including installing solar cells on the roof of the Cathedral of Magdeburg. Four years later, Japan instituted a similar program, except with 70,000 Solar Roofs. In the US, California is currently in the middle of a 10-year $3 billion dollar solar program started by the Public Utilities Commission in 2006 [1]. President Obama also recently announced in October of 2010 that solar panels and a solar hot water heater will be added to the White House roof, leading the way for the country [3]. Figure 1 shows of the progress in the efficiency of photovoltaics since their creation.

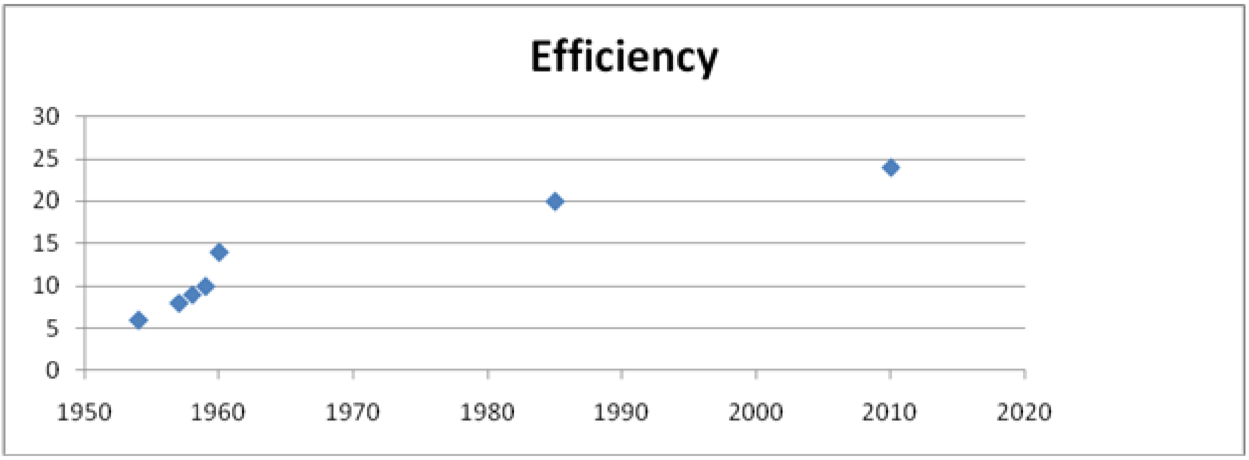

Figure 1: Efficiency of Solar Panels through History.

Figure 1 represents the efficiency levels achieved when converting sunlight into electrical energy. As shown, efficiency started at 6% in 1954 and rose through 1960 when the technology evolving the efficiency was halted for 25 years at 14% [1]. The available efficiency level was then increased to 20% in 1985 and again to 24% in 2010. Since 1960, the increase in efficiency level has been very slow, but it continues to increase which is an encouraging sign.

2.2 Government Involvement in Photovoltaics

As a major new invention with potential for mass production, the government took an interest in photovoltaics. During President Carter's term in office from 1976-1980 one of his councilmen who was in charge of environmental quality predicted in 1978, that by 2000, solar energy could account for 23% of the energy use in the US. The likelihood of meeting this prediction looked promising in the late 70's, with the sales of photovoltaics increasing by a factor of 10 from 1975 to 1977. During the presidency of Reagan following that of Carter, though, the numbers decreased dramatically due to research budget cuts. Figures 2 and 3 show the Researh & Development (R&D) for Renewable Energy Sources from 1984 to 1995 for some of the countries in the IEA (International Energy Agency).

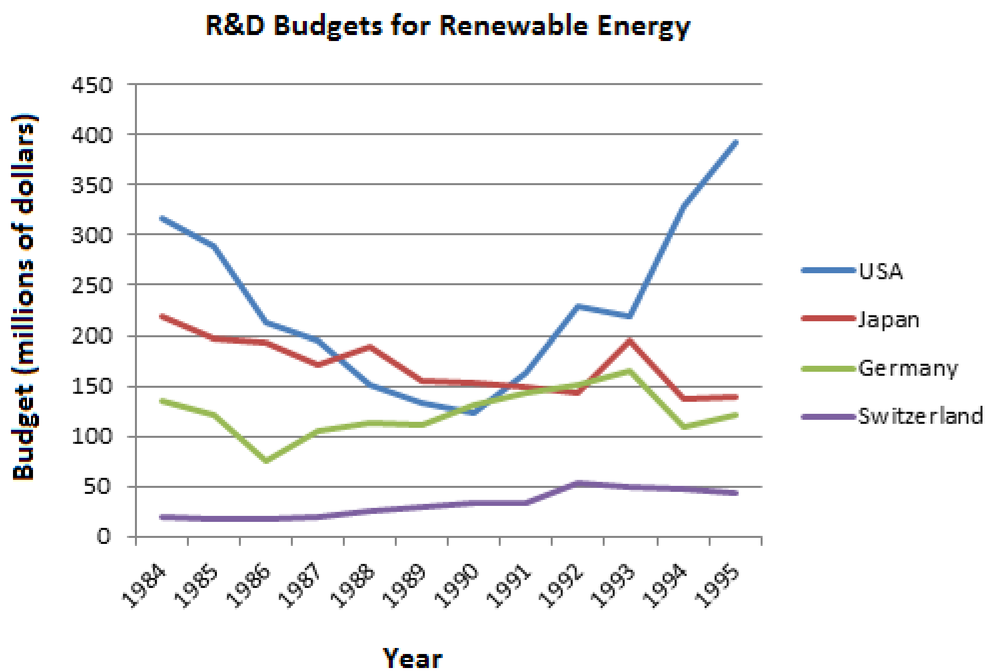

Figure 2: R&D of Major Countries around the World [4]

This figure shows the budget allotted for the investments in Research and Development for Renewable energy in the millions of dollars. It is learned from here that the US made the greatest R&D investment in the world for a majority of the time period, and Switzerland was one of the lower budgeted countries in the IEA. Note that Figure 2 just shows the amount of money each country had budgeted and not how these values correlated to their population at that time [4].

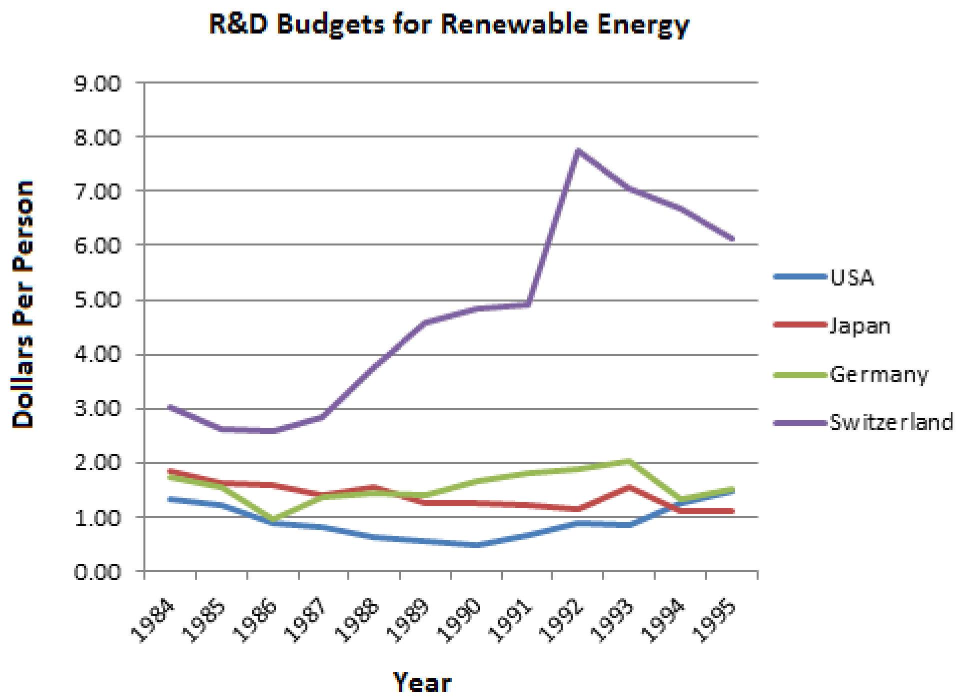

Figure 3: Money Spent per Person for R&D of Renewable Energy [4], [5]

Figure 3 shows the amount of money spent on research and development of renewable energies from 1984 to 1995 for the US, Japan, Germany, and Switzerland per the population of each country. As shown, the US had the least amount of money spent per person for most of that time period, whereas Switzerland was spending multiple times as much as Japan, US and Germany per person. So even though Switzerland's total budget was far less than that of most other countries per the previous graph, their per person expenditures were quite high [4], [5].

"Solar energy works. We know it works. The only question is how to cut costs." [6]. This quote by President Carter sums up one of the main problems with using photovoltaics: the cost. The government knew even then that the resources needed for the production of energy would not last forever and that another way needed to be found in order to be able to continue to live the way we do. "So we continue to live in a state of permanent contradiction, suspended uncomfortably between the undeniable scientific evidence of the destruction of the environment and the obstinate refusal of the overwhelming majority in politics and industry to appraise seriously the opportunities of solar energy." [7].

Knowing that photovoltaics were potentially a viable option for the future as long as the technology increased and price dropped, scientists kept on working on their evolution. And as the environmental repercussions of energy production methods of the time became more and more apparent to the government in the 1990's, questions about alternatives to fossil fuels and nuclear power plants became more & more frequent. Again, refer to Figure 2 showing the budget increase for R&D for renewable energy sources at that time.

The government has provided incentives for the general public to adopt the concept of photovoltaics by creating the Renewable Energy Act and the Feed-In Tariff. These campaigns encourage people to implement photovoltaics cell usage into their homes in order to decrease their electric bill. Whether these cells are able to replace only a portion of the energy needed or all of it would be dependent on the total area covered by the installed cell(s) and the geographical location that governs the amount of energy collected. An additional incentive is that if the cells collect more energy than is used by the consumer, the National Grid agrees to buy the excess energy per the Renewable Energy Act or the Feed-In Tariff. The Feed-In Tariff has been enacted by several states here in the US thus far, but the amount of compensation varies based on the time of day and which state it is. There are some restrictions on this tariff to reduce risk of excessive payment by the National Grid. Vermont has set the limit at 2.2 megawatts for an individual photovoltaic system; anything more and the grid won't buy it back [8]. Until recently, the California grid was not in the practice of buying excess energy back from a consumer with a renewable energy source, but instead would just subtract the value of the produced energy from their electric bill.

Feed-In Tariffs have been implemented all across the world and are currently used in 75 countries, states and provinces. The goal of this tariff is to “encourage, rapid, sustained, and widespread renewable energy development” [9]. Europe has successfully shown how well this tariff can work if applied correctly. Germany currently pays 56 cents per kWh to homeowners and “Portugal gets nearly 45% of its electricity from solar” [10]. This compared to the US is ginormous; the US gets only 10% of its electricity from renewable sources and the price is around 30 cents per kWh depending on the time of day and state. From 2000 to 2009, Europe has deployed 15,000 MW of solar photovoltaics and 55,000 MW of wind power. The US currently has only some states where the Feed-In Tariff is enacted, and continues to face the challenges of each individual state having their own regulations and prices for buying back the energy.

2.3 Environmental Effects of Photovoltaics

Current methods of producing electricity create negative environmental impacts. Being able to quantify the degree of impact for each method is an important step in determining if photovoltaics may better suit the world from an environmental perspective. “Power plant pollution is responsible for 38,200 nonfatal heart attacks and 554,000 asthma attacks each year.” in the US [11]. These values that were collected by scientists from the University of Maryland give a rough idea of how greatly pollution affects our society each year. Whether it’s nuclear power plants, coal plants, or photovoltaic plants, they all produce certain negative effects on the environment and our society.

The overall amount of land required and its impacts to the surrounding land is one of the concerns with electrical plants. Coal plants require relatively small amounts of land for the actual storage of coal and the plants themselves. Coal mines on the other hand require a much larger portion of land in comparison to that used for the plants. In total, electricity produced from coal occupies about 5 to 18 miles squared per plant. Some of this can be restored when the mines are depleted, but acid drainage along with other negative effects of mining still remains. The disposal of fly ash and slurry from the large smokestacks also require removal and more land [12].

Uranium mining and milling directly consumes on average 3.3 to 5.6 miles squared which is fairly small in comparison to that of coal. Unfortunately, this is just the directly correlated land and there are airborne and aqueous emissions that also disperse and consumer much larger amounts of area. The disposal of wastes related from nuclear reactions also takes up land which "would deny additional areas to extensive human use for many centuries…" [12]. These wastes can controlled to a certain extent by storing them underground in a contained area. The plants themselves are fairly compact in size and produce a fairly large amount of energy so they are centralized and fewer plants are needed [12].

Due to the large area required for solar farms, photovoltaic plants tend to use between 10 to 40 miles squared for their production of electricity. Different areas are more susceptible to collecting more energy than others as shown in Figure 4, so most farms tend to be in the southwest in the US. There is also land needed for photovoltaic disposal after their lifetime has expired (usually around 20 years), and depending on the material used, different measures need to be taken. If the solar panels consist of silicon, then just any regular landfill can be used, but if they consist of gallium arsenide or cadmium sulfide, the photovoltaic arrays need to be placed in a remote location with no possibility of access to water forever. Arrays made of those materials release toxins that can severely affect the drinking water [12].

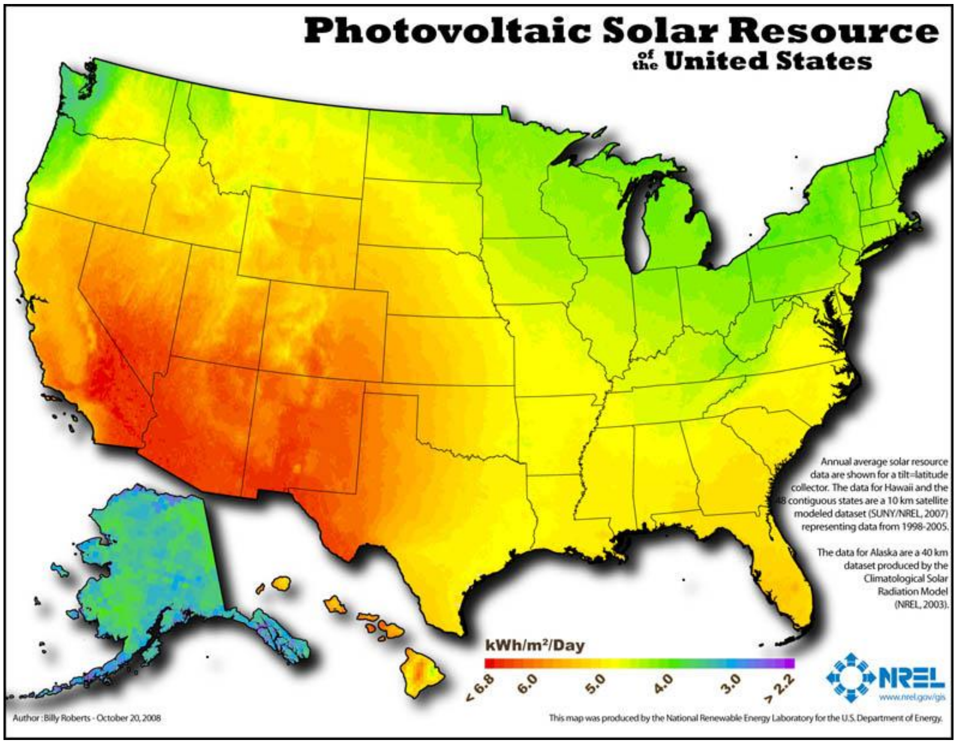

Figure 4: Amount of kWh per meter squared per day across the US [33]

An idea worth considering reducing the amount of land needed might be for companies to integrate photovoltaics directly into their building itself. In this instance, there would be no addition land used. This can also be applied to domestic applications as to power a household, or other small needs. Another consideration for solar energy, since sunlight is not always available, would to invest in an energy storage device that could be used to hold the energy for times when sunlight is not obtainable.

Emissions and pollution from production are also something to look at from an environmental perspective. Coal produces an immense amount of unwanted byproducts throughout its conversion into electricity such as carbon dioxide, sulphur dioxide, nitrogen oxides, and ash. These appear mostly during the energy conversion process, but additional emissions are developed during mining, the transportation, and the storage of coal. Coal burning byproducts lead to acid rain which falls back to earth and affects not only the water supply, but the soil too. Due to acid rain, the pH of the soil is lowered, directly impeding nitrogen fixation which is essential for plant growth [13].

Nuclear plants operate at high temperatures resulting in the production of poisons such as radon and its radioactive daughter products. These emissions are then dispersed into the air and can linger for thousands of years [12]. The more dangerous factor to consider with nuclear plants is the chance for a malfunction. Although the chances of this are very small, accidents have occurred that have released radiation to the surrounding areas affecting the lives of the surrounding population. The last incident where there was an issue with a nuclear power plant hasn't occurred for quite some time showing that our knowledge with relation to nuclear energy has increased since its discovery.

For photovoltaic pollution, the refinement of the different types of materials used to make the arrays (Silicon, Gallium Arsenide, and Cadmium Sulfide) is the main concern although it is small compared to that of nuclear energy and coal refinement. The processing and handling during the manufacturing of CaS (Cadmium Sulfide) and GaAs(Gallium Arsenide) produces some potential risks for the workers that come into contact with them. There is also the chance of emission exposure when photovoltaics used in a residential setting are burned during house fires. This risk is only a concern for houses with Gallium Arsenide material used for the arrays. Silicon photovoltaics appear to be the least hazardous material [13].

3 Economic Opportunities:

When considering a large scale incorporation of photovoltaics, there are resulting factors that should be investigated. One of the arguments against photovoltaics is that, with their low efficiency level, it is an impractical investment since they are not yet an effective way of converting the sunlight into energy. This argument has not been substantiated in the past with other products. In US history we have frequently spent money on the latest and greatest technologies even before they're potential had been maximized. The same could apply to photovoltaics. "The spectre has been raised that it may be a mistake to start mass production of a technology that may later prove to be outdated. The production of TV sets was not deferred until color TV was available, nor did the production of radios wait until the advent of multi-frequency receivers!" [14].

3.1 Costs and Sales:

As sited above, President Carter hit on one of the most pertinent issues with photovoltaics, the price. The time it takes for the invested cost of photovoltaics to create a return on investment takes years and years. With the average lifetime of a solar cell being about 20 to 25 years, the average person may see it as impractical to implement photovoltaics use into their life. Most the consumer does not understand the relevance of the type of method used for the production of their energy, and they solely consider the price. If the prices of the cells were lower or there was a quicker return rate, people might be more inclined to use solar energy.

When comparing the price per kilowatt hour between that of coal, oil, gas and solar energy with relation to money spent to get 1 kilowatt hour, the results are astounding. One ton of coal can be converted to 6,182 KWH. With one ton of coal being about $36 in 2006, the price per kilowatt hour is calculated to be $0.006. One barrel of oil can produce 1,699 KWH and cost about $70 in 2006. The price per KWH for oil was calculated to be $0.05. One cubic foot of gas can yield 0.3 KWH at a price of $0.008 in 2006, resulting in a price of $0.03 per KWH. All of these values are reasonably close together, but when compared to solar energy, they are extensively lower. A 5-KW solar energy system costs about $45,000. When taking into account DC to AC conversion (assuming 90% efficiency) this system becomes a 4.5 KW system. The average amount of peak collection hours during a day is 3.63, so this gives us about 16KWH per day. Multiplying this value by 365 to get the annual amount of KWH, you get 5,962 KWH and assuming the average lifetime of a solar system is 20 years, the total amount of energy collected is 119,246 KWH. In conclusion, the price of solar energy is about $0.38 per KWH. This value is more than 7 times that of oil which is the most expensive of the previously mentioned. The prices of each form of energy conversions per kilowatt hour are depicted in Figure 5 [34].

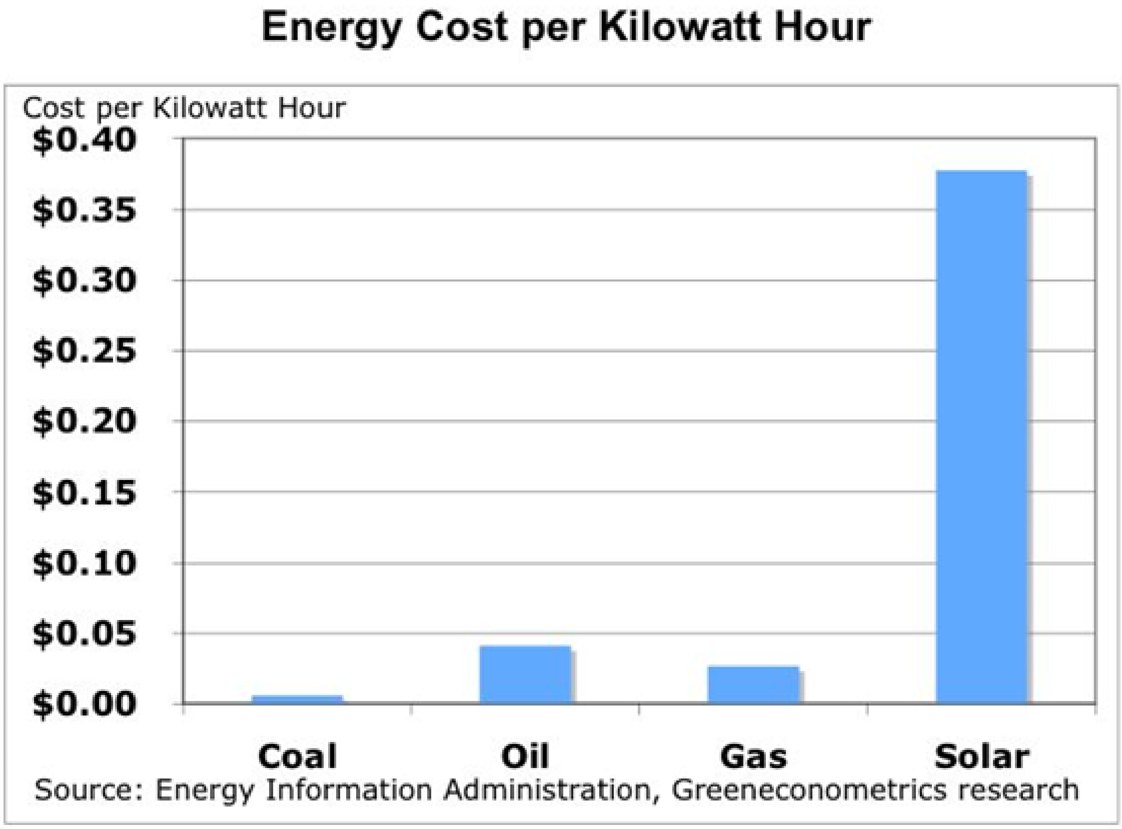

Figure 5: Energy Cost per Kilowatt Hour [34]

The energy required to produce photovoltaics is also a factor when considering return on investment time. This energy currently used to create these solar cells is most likely produced from fossil fuels or nuclear plants which are the solar cells' direct competition. The ultimate goal of using solar energy is to move away from these methods and produce clean energy, but like all things, it takes time for this to happen. Eventually, solar cells will be able to be produced fully using solar energy. The time it takes for solar cells to generate the same amount of energy that was used to create the cell is about 3 to 5 years. Although this time span allows for plenty of additional years to make the invested money back over the lifespan of the cell, it is much larger than that of nuclear power plants and coal plants. Nuclear and coal plants see a positive net energy values after about 7 months. With that shorter payback time in comparison, investors are more inclined to put their money into nuclear and coal plants rather than photovoltaics so they can make money faster.

Even with the high prices of today, photovoltaics sales have been increasing since the year 2000. This trend is expected to continue as the world becomes more and more aware of the limited availability of fossil fuels. As the technology related to the efficiency of photovoltaics also increases, people will also be more prone to purchasing solar cells. Figure 6 shows the charted sales of solar cells and modules from 1999 to 2008.

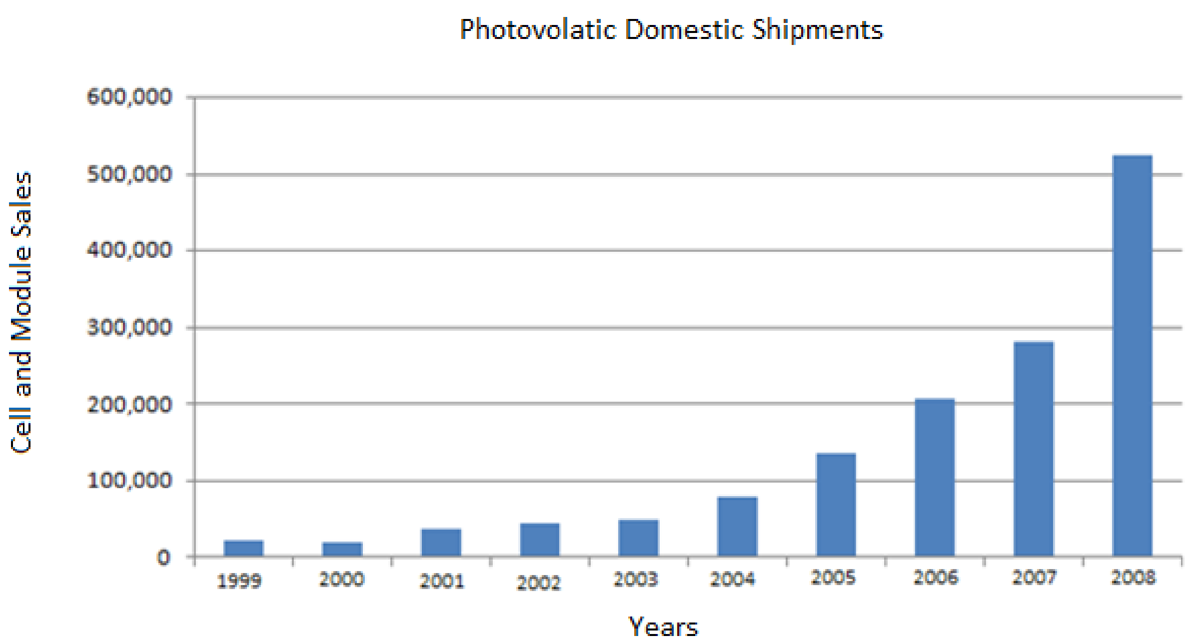

Figure 6: Sales of Photovoltaics for Domestic [15]

Figure 6 shows an increase that resembles an exponential curve, but will eventually level off if solar cells become installed everywhere. This plateau would not very likely to occur for many years to come. The sales should not follow the path of a parabolic function either, because solar cells have a limited lifetime and will need to be replaced about every 20 years. Even if they have been previously installed at a specific location, new solar cells would have to be purchased to take the place of the old ones.

3.2 Resulting Jobs:

With the implementation of photovoltaics on a large scale, a massive increase in new jobs would occur. Positions involving the actual building of the arrays, distribution of finished goods, the installation of them for residential and industrial purposes, and routine maintenance of them would provide a plethora of jobs available to the public. "The cost of solar energy is higher not because of the cost of the primary energy but because of labor costs." [16]. The World Watch Institute estimated the number of jobs that would be needed for the production of 1,000 GWh/year. The results are shown in Figure 7.

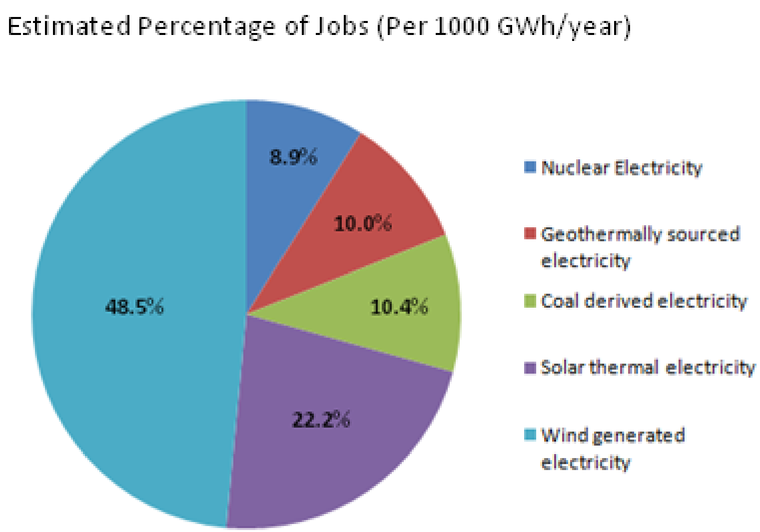

Figure 7: Estimated Percentage of Jobs per Type of Electricity Production [17]

As shown in Figure 7, Nuclear Energy is predicted to require the least amount of employees to produce 1000GWh/year at 8.9% out of all electricity related workers, whereas

Wind Generated Electricity requires the most. The renewable energies, wind and solar thermal electricity, account for more than 70% of the jobs that are required to produce 1000GWh/year. This would lead to more jobs around the world increasing the global economy as a whole.

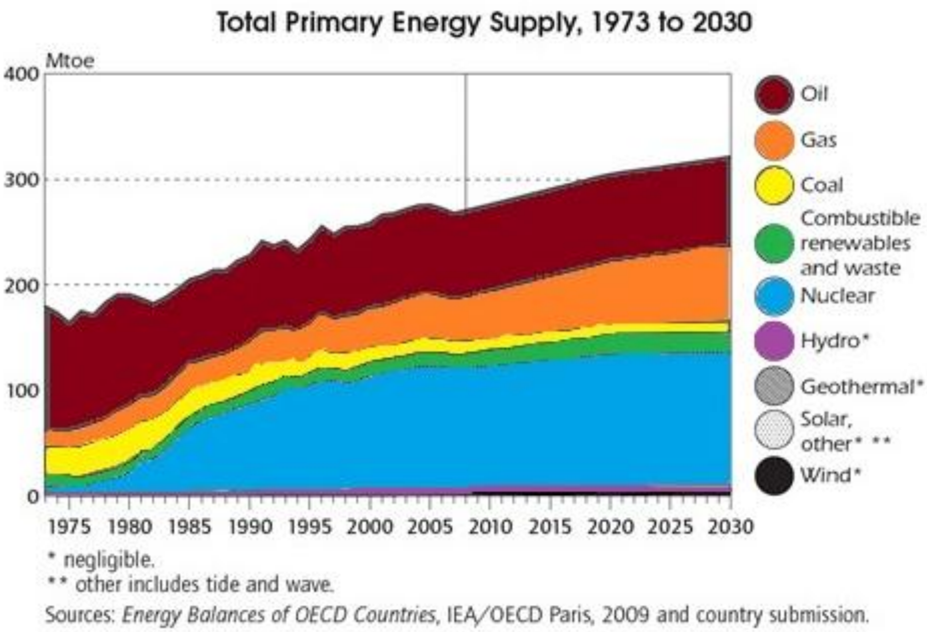

Figure 8: Past and Projected Energy Supply [18]

Figure 8 shows that solar and wind energy supplies are virtually non-existent even through 2030, whereas nuclear energy will account for the majority of the world's energy. Fossil fuels such as oil, natural gas, and coal will still be producing a large portion also, even through the next 20 years, according to this projection. When compared Figure 2, it is hard to believe that even though wind and solar energy make up what appears to be only around 1% of the world's primary energy supply through 2030, wind and solar thermal electricity account for 70.7% of the jobs per 1000GWh/year. The implementation of solar and wind power plant energy will require workers to build the buildings that would harness the energy, along with the increased production line to keep up with the number of solar cells needed around the world. Installation and maintenance workers will also be needed, whereas current methods involving energy production already have buildings and workers already in place. An example of one vocation that could see no change or possibly a reduction in jobs could be for roofers if for example, solar cells were able to be integrated into roofing shingles. With specialized installation training, roofers & solar cell installers could become one job. So while photovoltaics would lead to an increase of many jobs, it could also be taking the place of some other current jobs.

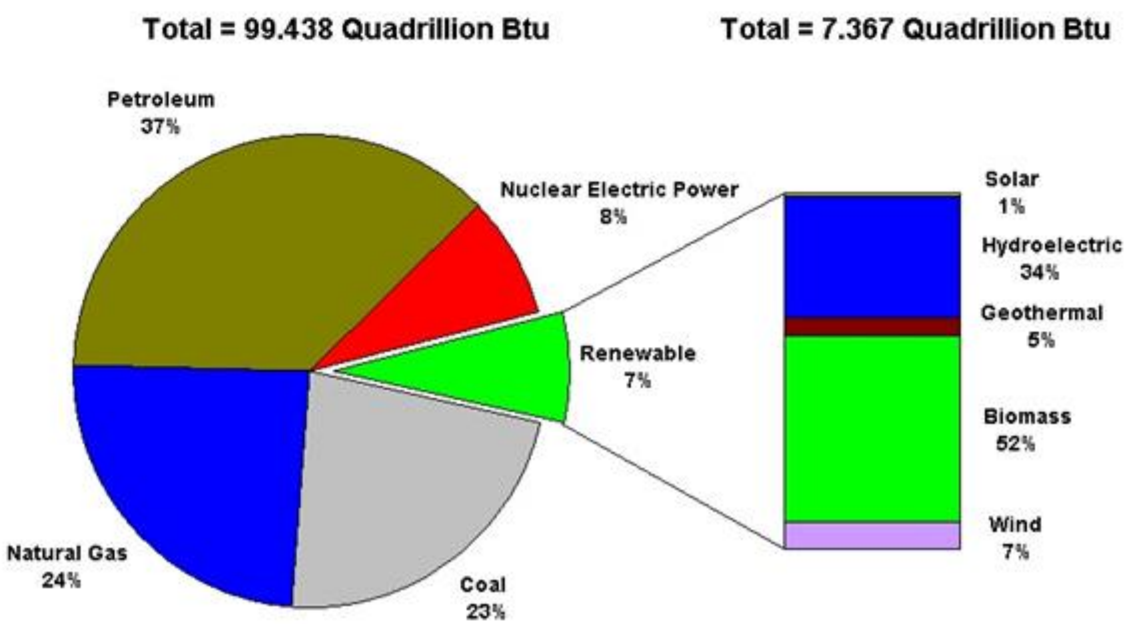

Figure 9: Amount of Energy used by the US [19]

Figure 9 tells us that the US used 99.438 quadrillion Btu's of energy in 2008. Each Btu is equivalent to 0.293Wh, so the US used 29.14 quadrillion Watt hours of energy that year. Of that, only 7% was generated from renewable energy sources which is 2.15 quadrillion Wh. To break it down even further, only a minuscule 1% of the renewable energy used in 2008 was obtained from solar energy. When calculated out, solar energy only accounted for 21.5 trillion Wh of energy. Petroleum represents the largest portion of the pie chart, most likely being used by automobiles in the US. With the diminishing amount of oil left in the world, the price will continue to increase as the need becomes greater than the supply that is left. As scientists have been looking into alternative ways of being able to power cars, the electric car has been gaining more and more promise over the last few years, and is becoming accepted as the car of the future. Could harnessing solar energy during the day to charge an electric car battery at night could be the wave of the future?

4 Results

Photovoltaics should not only be considered just for the fact that the world is running out of fossil fuels. Ways that solar energy can contribute to improved health of the public with relation to energy production should also be documented and shared. Air pollution is a side effect of current energy conversion methods involving coal. Additional metrics should be gathered & recorded on coal methods, for they can leads to diseases such as asthma and an increase in greenhouse gases.

4.1 Asthma

Asthma is an ever growing epidemic in the world today, and with it are direct and indirect effects on the community. "With upwards of 130 million asthmatics worldwide and an estimated 15 million within the United States (Birnbaum, et al. 2002: Cleland, et al. 2003), it is very easy to see that asthma can have a negative impact on any economy. In the United States alone, it has been estimated that asthma accounts for 2-5% of the economic cost of all diseases with a staggering 13 billion dollars in cost (Birnbaum, et al. 2002: Cleland, et al. 2003). With an average cost of approximately 5,000 dollars per asthmatic, there is an incentive to develop new costing techniques and better asthma control (Cisternas, et al. 2003)" [20]. "An estimated 1.5 million hospital visits were charged to asthma related conditions in 2002, with 30% of those stays requiring expensive treatments such as nebulization therapy" [21]. These are the direct effects of having asthma.

The indirect effects of asthma take quite a toll on the economy as well. "Asthma is the number one cause of workforce disability and the fifth most common cause of workplace limitation (Cleland, et al. 2003). Upwards of 2,000 dollars can be lost per year by the average asthma worker for just loss of work time. This does not account for decreased productivity or decreased hours of work per day that many asthma patients must take (Cisternas, et al. 2003)…" [22].

The direct and indirect effects of asthma are definitely something to consider when looking at the numbers. "During periods of heavy air pollution, there tend to be increases in asthma symptoms and hospital admissions. Smoggy conditions release the destructive ingredient known as ozone, causing coughing, shortness of breath, and even chest pain. These same conditions emit sulfur dioxide, which also results in asthma attacks by constricting airways" [23]. Rather than developing new costing techniques and better asthma control, consideration should be given to attacking the root of the problem: poor air quality.

A possible way to lower air pollution is to reduce the amount of combustion engine cars. A suitable replacement for a combustion engine vehicle would be the electric car. This would lower emissions locally, but still require the electricity to be harnessed somehow.

The Los Angeles region has one of the highest levels of air pollution in all of the US. A layer of smog can be seen hovering over LA in Figure 10.

Figure 10: Photo of Los Angeles [26]

This is commonplace for people in LA and is definitely not healthy for the residents of this area. There is a federal standard for the concentration of smog, and the South Coast Air Basin exceeds that value for a large portion of each year. The South Coast Air Basin consists of parts Los Angeles, San Bernardino, and Riverside Counties and all of Orange County. Figure 9 shows the history of the concentration levels of smog in this area, along with the number of days that this area exceeds the federal ozone standard.

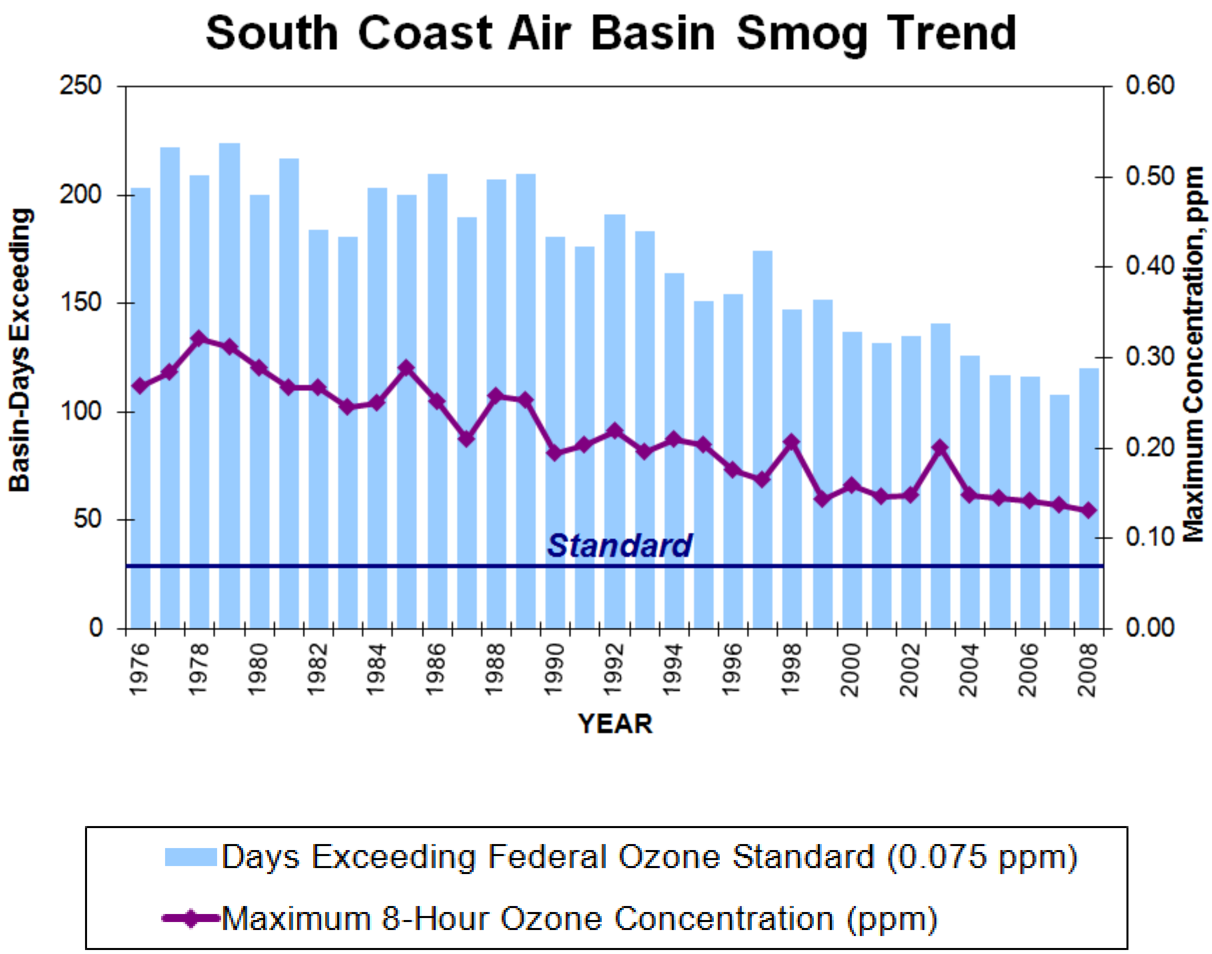

Figure 11: South Coast Air Basin Smog Trend [27].

The trend of Figure 11 moves with a negative correlation, lowering the concentration of smog and the number of days over the standardized value. Though the decrease is good, this region of the US is still over the maximum amount for a portion of the year that should be unacceptable.

In order to conclude that there is a direct correlation between pollution and asthma, some information should be taken into account. Figure 12 shows the crude rate of hospitalizations for asthma in Los Angeles County per 10,000 people.

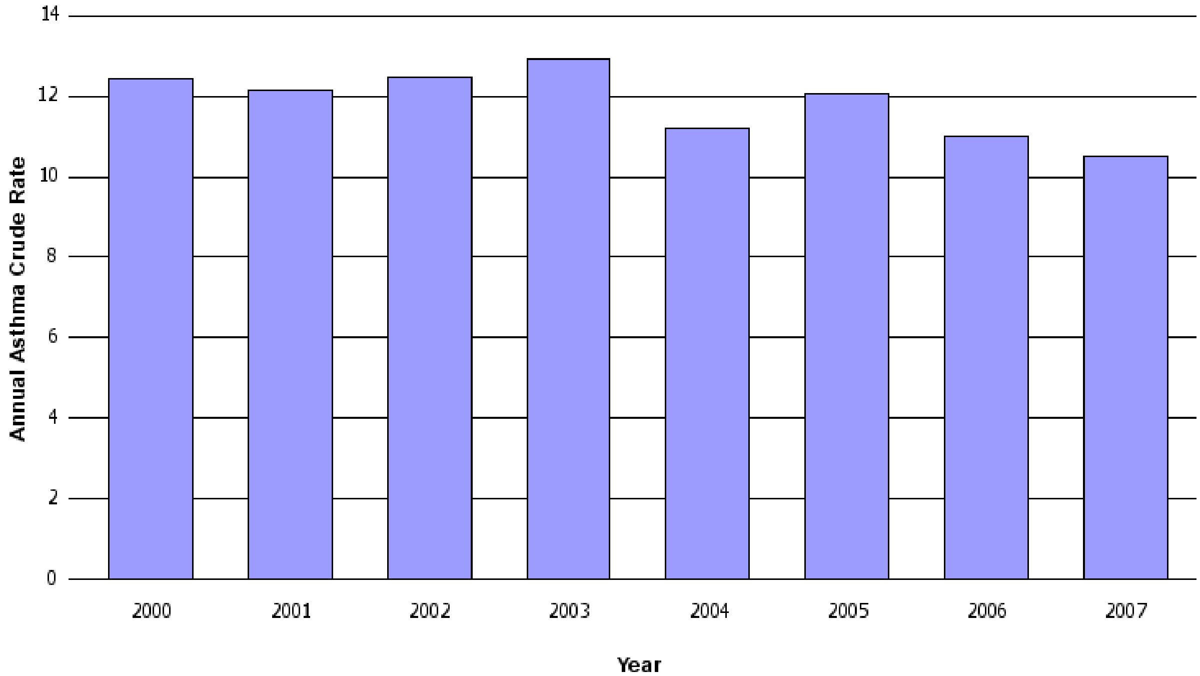

Figure 12: Crude rate of hospitalization for asthma in LA County per 10,000 people [24]

In 2008, the population in LA County was 9,862,049 so in order to see how many hospitalizations there were in each year, these results must be multiplied by about 986. This results in more than 10,000 people going to the hospital for asthma each year. Since the average number of cars per person in the US is 842 cars per 1,000 people [25], logically a city with more people would have more cars, but is there a connection between the number of cars giving off pollution and the number of asthmatics? Figure 13 shows the same information as Figure 12, except the location is different; Figure 13 is for Tolland County, Connecticut.

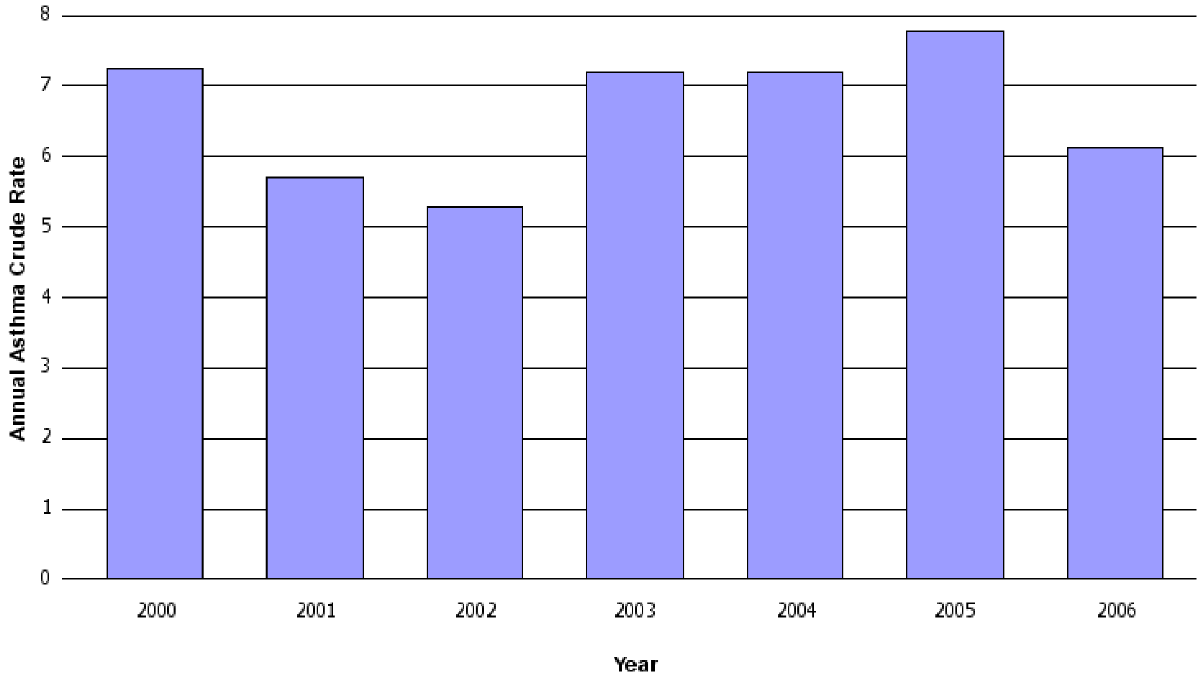

Figure 13: Crude rate of hospitalization for asthma in Tolland County per 10,000 people [24]

In 2008, the population in Tolland County was 148,406 so in order to correctly interpret this data we must multiply all of the results by about 14. Figure 13 in comparison with Figure 12 has less rates of hospitalization. This could be predicted because Tolland County has a much lower level of emissions. Figure 14 shows a direct comparison of the number of days with levels of emissions over the maximum between LA County and Tolland County.

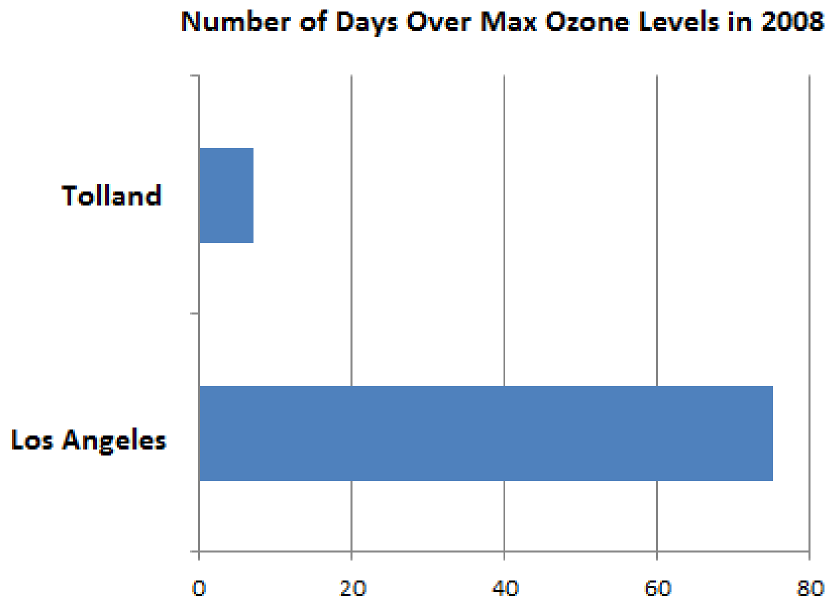

Figure 14: Number of Days over the maximum ozone concentration levels in 2008 for LA and Tolland County [24]

When looking at all of this information, one can come to certain conclusions. For example, LA has an excessive amount pollution compared to that in Tolland, but it also greatly exceeds the population of Tolland. Since the number of cars increases proportionately with the number of people, there are about 66 times as many cars in LA, releasing 66 times as much pollution. This size should also be taken into account though since LA County is about 10 times as large as Tolland County. Even still, LA is releasing more toxins into the air and affecting the health of millions.

4.2 The Electric Car

One of the leading causes of pollution today is from the use of the automobile. Emissions from the internal combustion engine mix with the air that we breathe each day which, over the long run, can negatively affect our health. The logical thing to do would be to try to reduce these emissions or remove them altogether. Scientists have been working on this problem for quite some time now, and hybrids and electric cars are ways to approach this problem.

Just like every new concept, there are some things to consider with this new technology. Hybrid cars use electric power for a certain extent and then switch over to gasoline. There will still be pollution involved with traveling, but every little bit counts and this would be a step in the right direction. The downside is that having two separate engines in the hybrids leads to more weight, and more energy is needed to run the car. Electric cars have less than a 200 mile range. This could be a problem if traveling for business or if going on vacation, but for the most part, the average person doesn't travel over 100 miles a day. "Recently, electric vehicle portal *THINK* announced a new standard for fast charging - zero to 80% charged in just 15 minutes" [28]. With this technology, electric cars definitely become more feasible as long as there is a surplus of charging stations that are widely dispersed. The electric car can also be charged through any regular household outlet and "Most can be re-charged in 30 minutes or less" [28].

Efficiency is another point of interest. Traditional gas powered vehicles experience only 20 to 25% energy efficiency, whereas a car such as the Tesla Roadster has an 88% efficiency. As traditional cars get older, their efficiency goes down even further while electric cars retain their high functional efficiency. Electric cars are recharged from a recharging station or from the grid. This energy can come from natural gas, coal, solar and wind energy. A set up as shown in Figure 15 is a possible way for "free fuel" to be used to power your car. This also has no pollutant emissions like that of the production of energy through means of coal [31].

Figure 15: “Charging station” for an electric car using only solar energy [31]

If electric or hybrid cars were to be implanted on a large scale across the United States, there would be some effects that would have to be taken into account. There would be a significant decrease in the amount of pollution in the air, which directly improves the health of the general public. There would need to be a plan for what to do with all of the current cars that aren’t electric. They would most likely become recycled, or broken down and used as spare parts for other machines. The most important thing to look at with the implementation of electric and hybrid cars is **when** charging occurs. There are two main situations when the charging could cause problems. The first is when the driver gets to work, and the second is when the driver gets home from work. In both cases, the driver is going to want to charge their car for its next use. If the majority of people on the east coast get to work at 8am and get home at 5pm, there would be an excessive demand in the amount of energy needed from the grid in order to supply the recharging of the cars during these times. This amount of energy drain could cause blackouts over wide spread areas. One possible solution to this problem could be the incorporation of photovoltaic generators. Like in Figure 15, a simple garage that has solar panels on the roof, could charge a generator all day and then be used to charge the battery of the car. Obviously, if it is not sunny out that day, or the generator is out of power, the battery would not be able to be charged by this method and there would need to be a backup option to plug the battery back into an outlet.

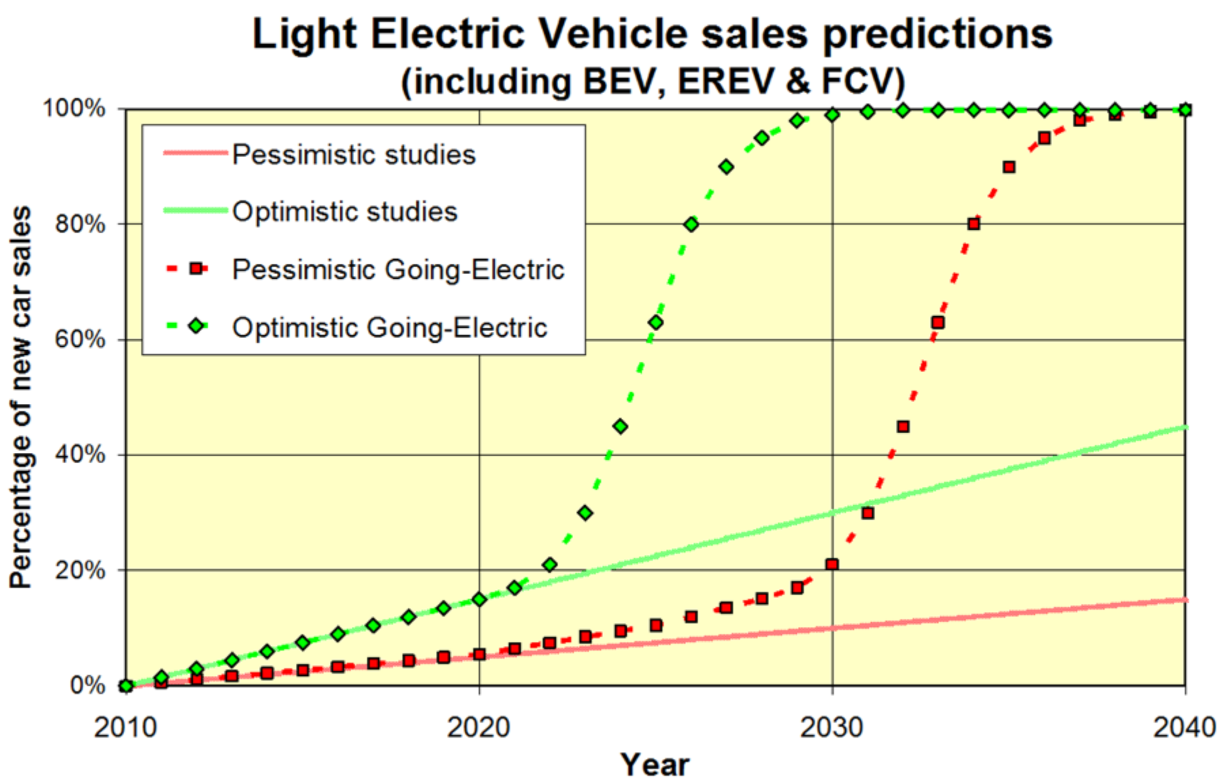

Figure 16: Predicted sales of the electric car through 2040 [29]

The Going-Electric organization has a few reasons to believe that the information in Figure 16 is going to be accurate, the first of which involves production. As more and more electric cars are produced and as the technology improves, there will be a reduction in the price, making them more competitive with the standard internal combustion engine cars. Another reason for their prediction is oil prices. With the number vehicles in the United States alone, around 260 million in 2008 [30], oil is quickly depleting. With rising oil prices, people will eventually steer away from the cost of traveling by gas and make the switch over to the electric car. Their last thought on why the electric car will become incorporated within this timeframe has to do with public regulations. Going-Electric feels that with consumer acceptability of the electric car, the government will impose restrictions on the use of internal combustion engine vehicles. This would eventually lead to the complete incorporation of the electric car. Note that the graph displays just the sales prediction, not actual percentage of all cars used [29].

Some people shy away from getting a hybrid or electric car because of the current price. Consumers think that it will take a long time to actually see a savings on fuel and that the price involved with replacing depleted battery packs is too high. J.D. Power and Associates, which deals with all forms of automotive research, said the following in relation to the electric car: "Power said for sales of cars like the Leaf and Volt to take off, gas prices will have to rise significantly. The industry also needs technological breakthroughs that lower the cost of the cars and support consumer confidence in the vehicles' batteries, powertrain and range. On top of that, the electric-vehicle industry may need government policies to encourage the purchase of such cars." [30]. This quote follows along the same line as what was predicted by Going-Electric. In contrast, J.D. Power predicts that in 2020, the sales of hybrid and electric vehicles is going to be around 7% which falls in the pessimistic range of sales predicted by Going-Electric as shown above in Figure 14 [30].

4.3 Prediction & Conclusion

Everything that has been presented needs to be taken into account if one is to make an educated decision as to the future of photovoltaics. Solar cells can be an integral portion of the industry that could greatly improve our way of life while also contributing to the improvement of the health of the public. As shown by Figure 1, the efficiency level of photovoltaics hasn't increased rapidly and is still below 25% efficient. Though further increases in the efficiency level of solar panels, the average person would certainly be more inclined to purchase them. The increased efficiency would likely result in an increase in the cost of the panels upon their introduction into the market, but would eventually go down as time goes on. With higher prices for more efficient panels, the consumer would have to weigh the pros and cons if they were to purchase a panel to see if cost or efficiency is more important. Even with the current low efficiencies, photovoltaics are still being bought for domestic use at increasing numbers each year. I believe that these sales volumes will continue to climb even with the potential for limited or no increases in efficiency for quite some time. My projections along with the sales from the past 9 years are shown in Figure 17.

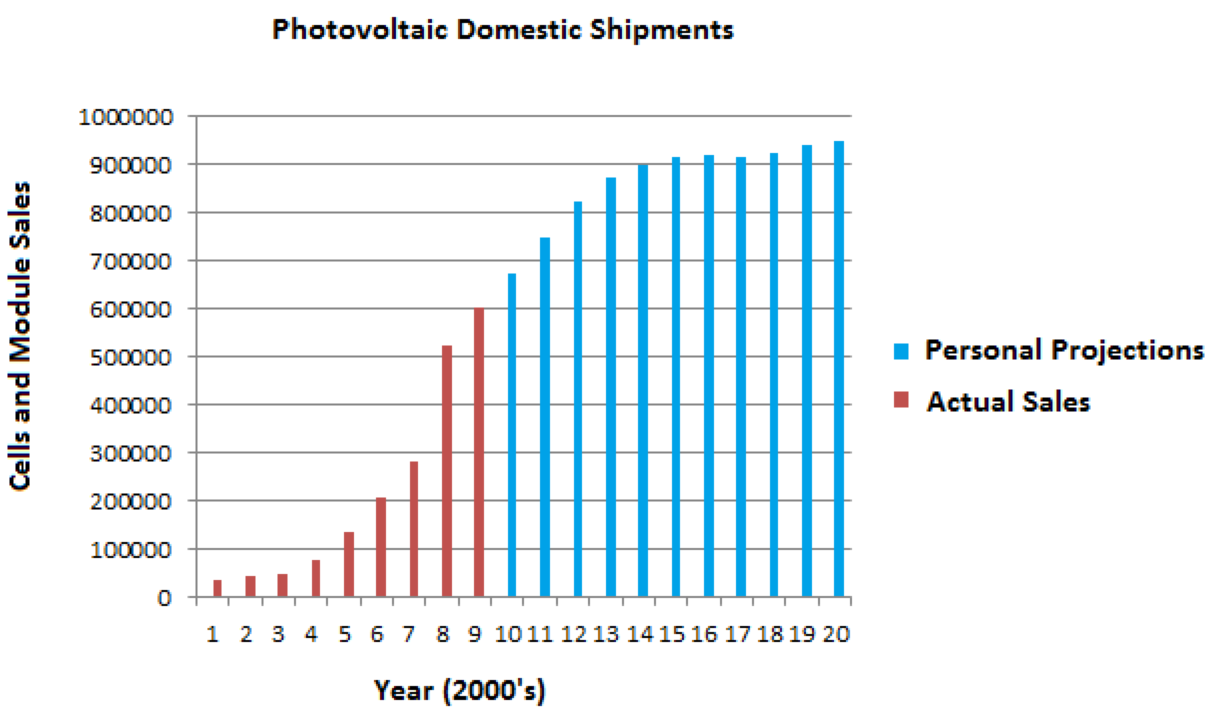

Figure 17: Personal Prediction of Domestic Sales of Photovoltaics

Since the sales cannot continue to increase at the rate they have been, my projections show a continued increase in sales over the next 5 years until about 2015, at which time I predict that the sales will level off around 930,000 sales per year. If the sales continued at their current pace, they would go to infinity, which isn't realistic.

Commercial sales rates of photovoltaics can also be projected. The use of fossil fuels for the automotive industry creates an excessive amount of pollution that leads to sickness and disease worldwide. As stated previously, the electric car is one solution that scientists have developed to work toward solving this problem. In order to recharge electric cars, photovoltaics could be used by the companies that own the recharging stations or the owner of the car themselves, making the electric car more 'green'. Figure 18 shows a personal projection in comparison to that of Going-Electric on the sales of electric cars.

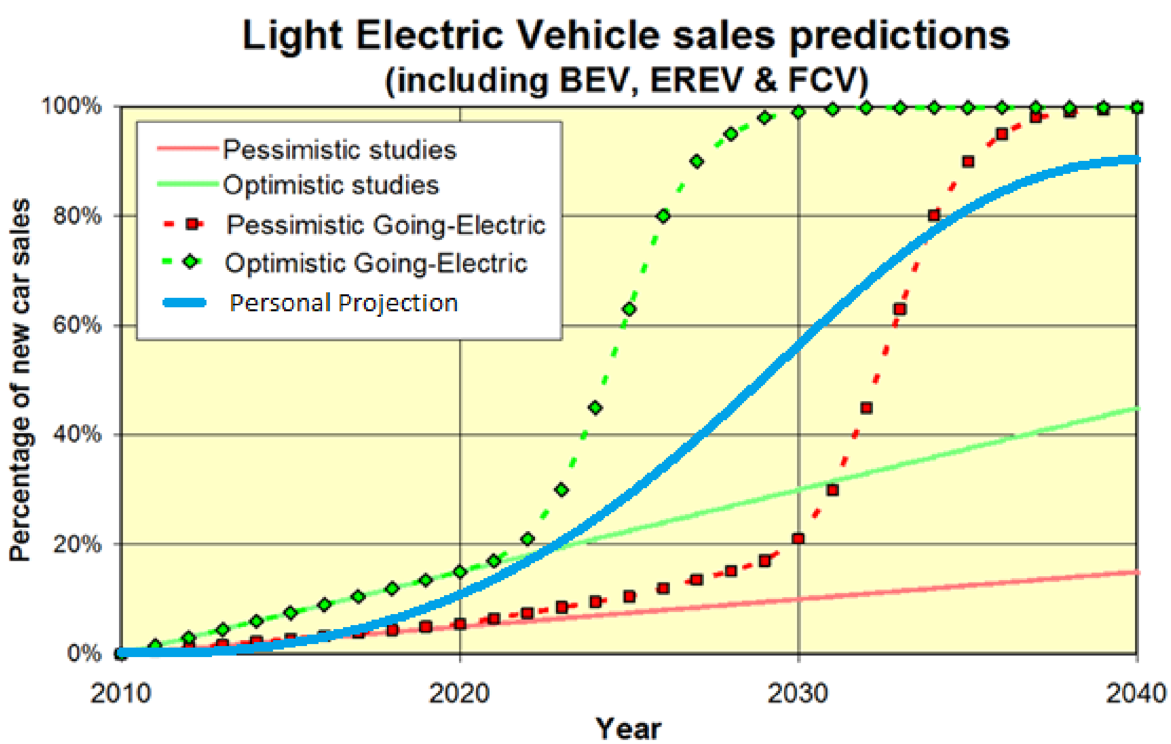

Figure 18: Personal Prediction about the sales of the electric vehicle.

As shown in Figure 18, I predict that the electric car will take up about 90% of new car sales by 2040. I believe that with the push that automobile companies are making towards producing electric cars is a sign of what is to come in the future, and as time passes, scientists will continue to improve their designs and performance. Just like all other available world-wide technologies, new ideas and inventions are being thought of all the time which is why I have predicted that the electric car would not account for 100% of sales like the suggested study suggests, I've left room for those future inventions.

If we take a global perspective and look at countries around the world, we can see movement toward the proliferation of photovoltaics. Countries around the world such as Germany and Japan have instituted large scale plans to implement photovoltaics in an effort to initiate a shift toward an alternative source of energy. In the US, California is leading the way for the rest of the country with respect to photovoltaics with a 3 Billion dollar plan. I believe that many other states in the US, along with other countries around the world will follow in the footsteps of these crusaders and begin to make the transformation towards a solar life. With these steps, who is to say that more transitions won't keep occurring, resulting in a domino effect where the whole world ends up being powered by the Sun.

Engineers across the world are making advances with the different types of panels used and the different materials that can be used to collect energy. Solar paint is one of the recent designs that is currently in development. This would be low in cost and a huge step in the future of photovoltaics. With this invention, solar energy could be everywhere, from the paint on your house to the paint on your car.

Fossil fuels that are quickly running out need to be replaced by a new means. There are many factors that that have been mentioned that are geared toward incorporating photovoltaics into society, but that doesn't mean that this will take place on a large scale overnight. Although, if the technology related to photovoltaics continues to increase as it has in recent years, and the price of fossil fuels continues to rise, solar energy could become a large part of our energy production. The resulting jobs are not enough reason to make the change from fossil to solar, but if and when the change occurs, the jobs will help to boost the economy worldwide. Scientists have known since it was discovered that the photovoltaic effect was the future of energy. I believe that the time is now to make the revolution happen. As said by Thomas Edison, "I'd put my money on the Sun and Solar Energy, what a source of Power! I hope we don't have to wait until oil and coal run out, before we tackle that."[32].

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