SOLAR POWER CONSUMPTION IN USA

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ABSTRACT

Sun is continuously emitting energy from billions of years and Sun stands as a primary source of heat for every living organism on the Earth. People used solar rays in many ways from many years. As technology increases, investment on research and development increased. The result is solar photovoltaic devices, that converts raw sun rays to pure electricity without emitting any toxic chemicals or not damaging any environmental footprints. United States is one of the leading solar energy producing country in the world, that has over 70 Giga Watt production in 2019. And increasing new installations every year in residential, non-residential, and utility sectors are their primary focus. This paper will include some numbers that indicates the increase of solar power, future of solar power, environmental impact by solar panels and more. Data comparison is the key in the paper which indicates the process and comparison between different sectors.

Keywords: *Solar Power, photovoltaic devices, Silicon cells, Sustainable energy, Climate change, Renewable energy, Semiconductors.*

Definition of terms:

Solar Energy: - the energy that is emitted by sun, usually we call it as sun light

Solar Photovoltaic device: - The Device that converts sun light (light energy) to Electrical energy by exposing the surface to the sun.

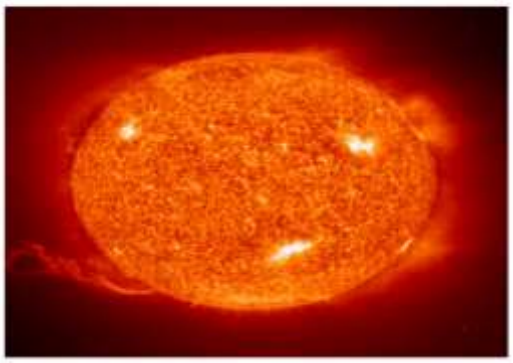
Watts: - Watts are the measurements for the electricity production.

INTRODUCTION

Sun is the basic power or source for any solar photovoltaic device**.** The production of solar energy is completely carbon free and less impact on the environment. This paper will discuss some data interpretation regarding the solar based electricity generation and photovoltaic device installation in USA over the past 8 years, from 2012 to 2019. The Data is collected in three categories, residential, non-residential, and utilities.

Figure 1

Sun emitting energy (NASA, 2020).



The figure 2 shows how the solar photovoltaic devices are installed to capture the sunlight directly.

Figure 2

Solar panels facing sun light

HISTORY AND DEVELOPMENT

The French physicist A. E. Becquerel observed the photovoltaic effect for the first time in 1839 (Fessler, 2019). His discovery was:

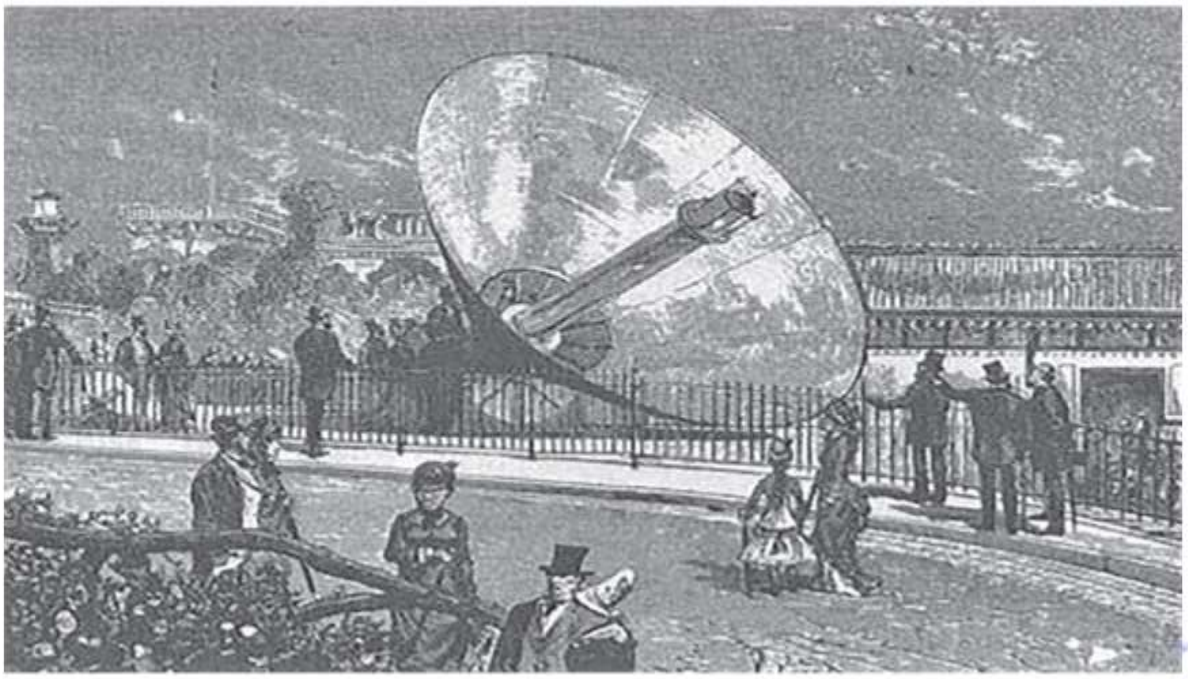
> "electricity is generated when different materials are exposed to sun light, this happens when material absorbs light from sun it causes excitation in elements to reach high energy state this results in generation of electricity".

In 1869 A French scientist named Augustin Mouchot, who has astute of imagining that all-natural resources will be emptied at some point and that will lead to a new industrial revolution with renewal energy as the primary source for all the machines. Then he built a steam engine that can work with solar cell (Fessler, 2019). The steam engine completely works with basic solar power. Where the engine works and generates power without any natural gas or liquid but only the sunlight on the photovoltaic device.

Albert Einstein was the first scientist who explained the Photoelectric in the year 1905 (Fessler, 2019). He elaborated all the photo electric effect and convened everyone and won Nobel prize in 1921 for his work. In 1954 a laboratory named three bell introduced silicon based solar sell. Their paper, "A New Silicon p-n Junction Photocell for Converting Solar Radiation into Electrical Power," appeared in the May 1954 issue of the *Journal of Applied Physics*.

Figure 3

Steam engine which works with solar sell



In 1958 NASA launched Vanguard I satellite with solar panels as energy source, which was the first to launch with solar PV (Nasa, 2021).

In 1991 USA government announced the establishment of National Renewable Laboratory under department of energy. With this the investment in research and development increased with installation of PV's increased.

RESEARCH QUESTIONS

1) How much solar Power is generated in USA over 8 years?
2) How much giga or megawatts of panels are installed in residential non- residential and Utility sectors?
3) Why USA is Not Using fossil fuels in generation of electricity even through, USA is one of the leading Producer of Crude?

LITERATURE REVIEW

With the high demand of energy in the market, the energy generated by fossil fuels is causing serious environmental problems. Like green house effect, acid rains, global deforestation and so on (Kumar, Sah, Singh, Deng, He, Kumar, & Bansal, 2017). To solve the ongoing disaster, companies should find an alternative for oil and gas which can be accepted by all the industries in the market (Sena & Ganguly, 2017). Increased population makes in increasing in energy production, the renewable energy is clean and non-toxic. Therefore, renewable energy is

popular in the world (Lee, Xiang, Schober, & Wong, 2015). Usage of solar energy makes less dependent on fossil fuel power and produces sustained energy (Johansson, McCormick, Neij, Turkenburg – 2004). "In Europe, Germany's cabinet has approved plans for a three-year pilot tender program to award 1.2 GW of new ground-mounted solar capacity, as a test for more far-reaching technology auctions from 2017 onward" (Sena and Ganguly, 2017). But the present development is on deducing the solar power fluctuation (Carrasco, Franquelo, Bialasiewicz, Galvan, PortilloGuisado, Prats, Moreno-Alfonso, 2006).

Nowadays EV vehicles are trending with less impact on the environment. If the EV's corporate with solar energy, the companies will gain profits and load profit can be track the generation curve. One strategy to combine EV's with solar power in charging stations Lee, Xiang, Schober, & Wong, 2015).

RESEARCH & DATA INTERPRETATION

Figure 4

Solar Installation and production of electricity in USA (2012 to 2019)

	New instalation		Instalation		
Year	Production	Total Production	Residencial	Non residencial	Utility
2012	3.313 GW	4.3 GW	0.49 GW	1.04 GW	1.79 GW
2013	4.751 GW	9.1 GW	0.8 GW	1.12 GW	2.9 GW
2014	6.201 GW	17.7 GW	1.23 GW	1.03 GW	3.93 GW
2015	7.260 GW	24.9 GW	2.1 GW	1.11 GW	4.0 GW
2016	14.626 GW	36.1 GW	2.58 GW	1.58 GW	10.59 GW
2017	10.600 GW	53.2 GW	2.27 GW	2.1 GW	6.2 GW
2018	10.600 GW	63.8 GW	2.5 GW	2.1 GW	6.2 GW
2019	13.300 GW	72.2 GW	2.8 GW	2 GW	8.4 GW

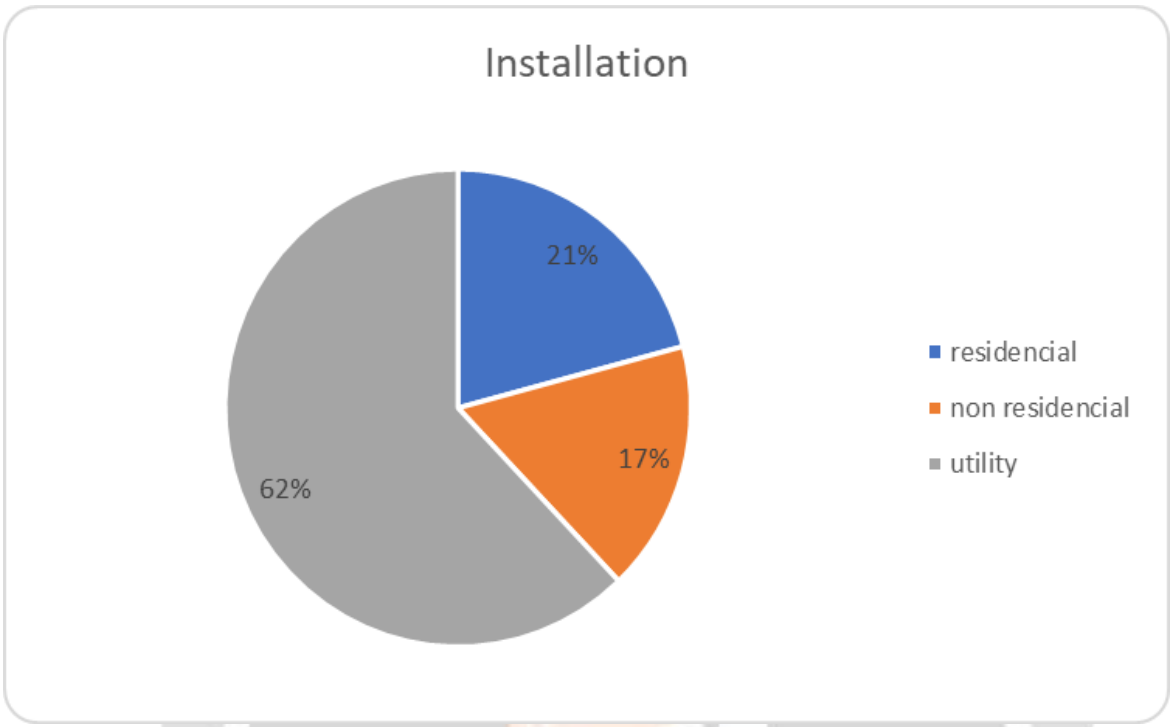
The data in the above table is collected from SEIA (Solar Energy Industries Association). This Association will announce all the productions of solar energy every quarter (3 months). Collected all the data and made a table to understand easily and to know how well USA is generating Solar power every year and this table also shows details about overall new installation which include Residential, Non-residential, and utilities. Used SPSS to interpret the data and plot the graphs.

The figure 4 data is all about electricity generation through solar energy in past 8 years over the united states. Column one indicates the year which we took the production. The second column is yearly production through out the year. The total production column indicates the cumulative production or overall production till the date.

The installation part is about the new installations every year in different sectors. Residential is where people opt to install their own solar cells in house. Nothing but mini solar plant for household. Non- residential is same concept as residential but its for the company or the organization, who uses the electricity. Utility, this section is kind of third-party solar generators, for example: - companies will generate electricity through solar power and then sell it to the household or companies in name of electricity usage. Above figure gives a clear power generation on each sector over eight years.

Figure 5

Pie diagram of total installations in different sectors



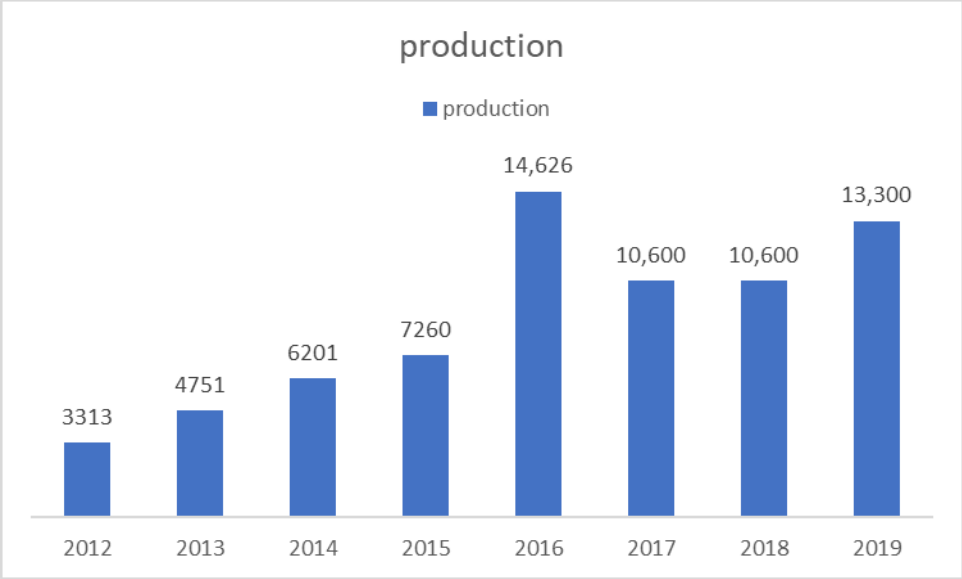
The above diagram shows the percentages of different sectors of installation, from 2012 to 2018. Utilities occupies 62.11% overall because investment of big companies will include utlities but not in residencial or non-residencial. Companies like (Reiff, 2020).

- JinkoSolar Holdings Co. Ltd
  - Revnue of 4.6 billion dollars,
  - Net income : 163.1 million dollars
- Canadian Solar Inc.
  - revenue of 3.2 billion dollars,
  - net income : 257.3 million dollars
- First Solar Inc.
  - Revenue of 3.1 billion dollars
  - Net income : 100 million dollars

These are some companies that has net income over 100 million dollars that's why utilities have major part compare to residencies, where prople have to invest personal money for getting a solar roof similar to industries those want solar energy plant.

Figure 6

Every Year Solar PV (New Installation)

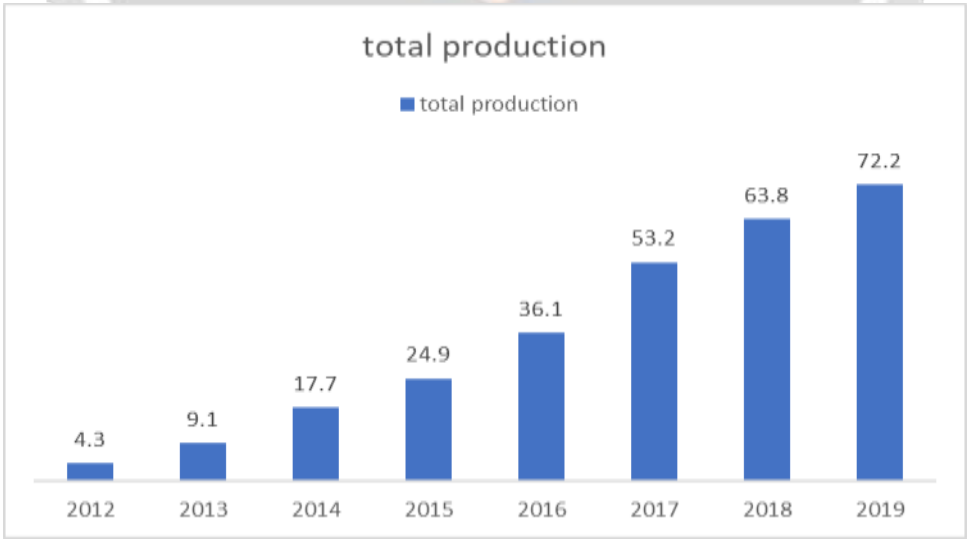


The graph (figure 6) showing the increasing in installation of solar PV's for past 8 years (2012 to 2019). Until 2015 it's a little growth about 15% to 20% but in 2016 it doubles because, 22 states invested more than 100 megawatts (Ferris, 2017).

> "There are now 1.3 million dollars solar installations across the United States, with a cumulative capacity of over 40 gigawatts. The Solar Energy Industries Association estimates that 1 megawatt of electricity can power 164 homes, so 40 gigawatts is enough capacity to power 6,560,000 U.S. households" (Ferris, 2017).

Figure 7

Total Production every year



The above diagram gives the numbers of each year of electricity production. We can see that every year it is increasing gradually from 4.3 terra Watts to 72.2 terra Watts. By this we can learn that demand for solar energy is increasing everyone year and it may increase in future. With the political support for sustainable energy this may increase substantially in coming years.

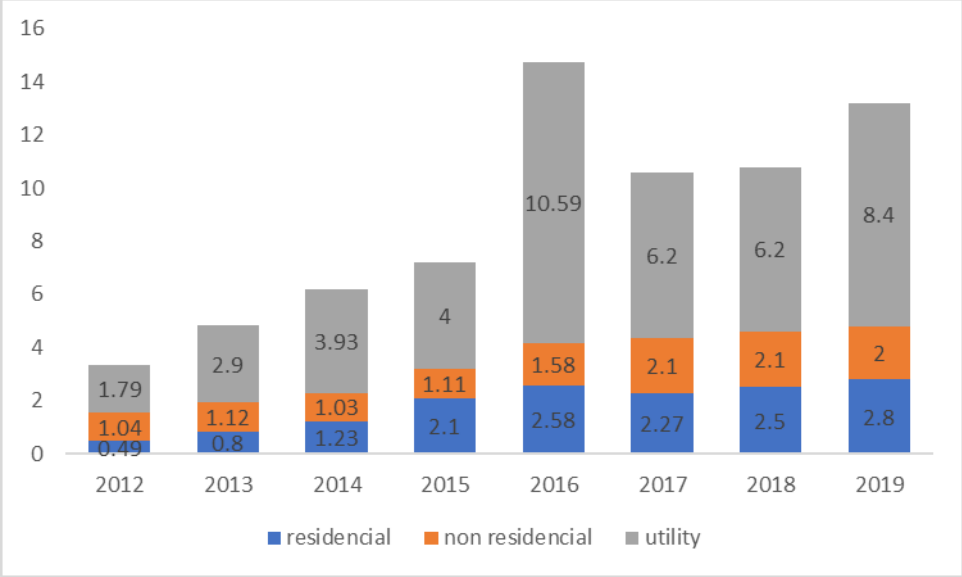
According to me in the near future USA may completely depends on renewable energy and most solar energy. Mostly the world may turn IC engines to electric turbines with solar powering.

Figure 8

New installation for Residence, Non-Residence, and utilities (trend)

Figure 9

New installation for Residence, Non-Residence, and utilities (histogram)



The graphical figures 8 and 9 above are the statical representation of different sectors. In the graph the colors are as follow Orange indicates Utilities, green id for Non-residence, and blue is for residence. The first one is

about yearly wise new installations of solar panels and second graph indicates the comparison between three sectors individually and yearly installation. As usual utilities occupies major portion compare to other two. In 2017 residence installation decreased as per the data. Same with the utilities it sores in 2017 by a lot of margin.

ENVIRONMENTAL IMPACT

While generating the energy from sun's radiation, we wont cause any air pollution or any other toxic gases. Creating electricity using sun will have a positive, indirect effect on the environment. Solar energy production will effect the other sources for energy production which are fossil fuels and may impact the environment in a positive manner.

However, there are some toxic chemicals that used in the production of PV's cell, which converts energy form. Some chemicals may leaks and damages the air and soil. That's why US environmental law regulates the use and disposal of this type of materials.

The PV cell manufacturing process includes variety of hazardous materials, most of which are accustomed clean and purify the semiconductor surface. These chemicals, kind of like those employed in the overall semiconductor industry, include acid, vitriol, aqua fortis, fluoride, 1,1,1-trichloroethane, and acetone. the quantity and sort of chemicals used depends on the sort of cell, the quantity of cleaning that's needed, and therefore the size of silicon wafer . Workers also face risks related to inhaling silicon dust. Thus, PV manufactures must follow U.S. laws to make sure that workers don't seem to be harmed by exposure to those chemicals which manufacturing waste products are disposed of properly.

Thin-film PV cells contain variety of more toxic materials than those utilized in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride[5]. If not handled and disposed of properly, these materials could pose serious environmental or public health threats. However, manufacturers have a robust financial incentive to confirm that these highly valuable and sometimes rare materials are recycled instead of thrown away.

BENEFITS AND LIMITATIONS

The following are some benefits and limitations of solar power usage in the market.

BENEFITS:

- **Renewable Energy source: -** Solar energy is generated by renewable source "sun". Sun is the basic source for heat from the creation of the earth. The best thing about this energy is, this is freely generated energy, and our work is to just capture it.
- **Reduce Electric bills: -** If someone installed solar panels on the roof or in the garden, this would help in saving 100's of dollars in utility bills.
- **Environmentally Friendly: -** compared to fossil fuels solar energy is non-toxic to environment and emits zero carbon by products in atmosphere.
- **Low Maintenance cost: -** Maintenance of solar panels are easy and less cost. The only backdrop is dust, that we must wipe in particular interval.
- **Technology Development: -** In capturing the solar power scientists are so desperate to increase the efficiency of the solar panels. According to a article written by Mukhopadhyay (2020).

"Crystalline silicon (c-Si) is the most used semiconducting material in solar panels, occupying more than 90% of the global PV market, although the efficiency is significantly under the theoretical limit (~30%). Solar cells made of alternative low-cost and high-efficiency materials are emerging."

LIMITATIONS:

- **Initial cost: -** Initial cost of installing any solar panel setup will cost more. For example, Tesla charges 31,000 for a 10KW solar residential roof. This is the reason people can't afford a solar roof.
- **Weather-Dependent: -** Some states are in USA are highly incapable of sunlight in winter (nearly 5 months). This will directly affect the capture of energy through sunlight. Weather is important for solar energy production.
- **Storage: -** The storage of electricity will add more installation cost and need enormous space to place batteries and the material used in batteries are not good for environment.
- **Area Usage: -** Solar panels take acers of land for installation and need human power to maintain. For example: - to produce one Giga Watt per year require nearly 2.8 acers of land (Green cost, 2019).
- **Usage of Material: -** Some materials used in manufacturing has some backdrops that can damage environment and some human need sources like water and soil. Cadmium and lead are the major portion of this materials (Gromicko, n.d).

FUTURE OF SOLAR ENERGY

In the coming years, technology improvements will ensure that solar becomes even cheaper. It could preferably by 2030, solar will became the foremost important source of energy for electricity production in a very large element of the earth. this may even have a positive impact on the environment and global climate change. Going forward the solar industry has very clear cost-reduction roadmaps, which should see solar cost within the future. there's already a move in towards higher-efficiency modules, which can generate more power than existing, similarly sized modules today employing a technology called silicon cells. These are visiting have an outsized impact going forward.

In addition, there are production innovations coming down the pipeline which will reduce the amounts of costly materials like silver and silicon employed within the manufacture of solar cells, similarly as innovations like bifacial modules which enable panels to capture energy from both sides. the alternative important innovation is around how best to integrate solar into our homes, businesses and power systems. this suggests better power electronics and a greater use of low-cost digital technologies.

> **"**Achieving the SunShot-level solar deployment targets—14% of U.S. electricity demand met by solar in 2030 and 27% in 2050—could reduce cumulative power-sector GHG emissions by 10% between 2015 and 2050, resulting in savings of $238–$252 billion. This is equivalent to 2.0–2.2 cents per kilowatt-hour of solar installed (¢/kWh-solar). Similarly, realizing these levels of solar deployment could reduce cumulative power-sector emissions of PM2.5 by 8%, SO2 by 9%, and NOx by 11% between 2015 and 2050. This could produce $167 billion in savings from lower future health and environmental damages, or 1.4¢/kWh-solar—while also preventing 25,000–59,000 premature deaths" (Solar energy & renewable energy, n.d).

CONCLUSION

USA have increasing its solar energy production from last 8 years. The production increased from 4.2 terra watt to 72.2 terra watt this is nearly 18 times increase. This effected environment by a change because less use of Fossil fuels in generating electricity. This increment is not preferred to utilities and industrial sector, but normal house holders are preferring more to have a solar roof than paying utility monthly. Every sector which uses solar energy are drastically increased in production of electricity. By the data we know that USA is turning their wheels towards sustainable energy production because of climate change.

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