

Development Prospects for Nuclear and Solar Energy in The U.S.

Zeqin Song *

San Domenico School, Marin City, the United States

* Corresponding Author Email: zsong26@sandomenico.org

Abstract. Global-wise, Fossil fuels dominate the global energy mix currently with significant drawbacks, for example, increasing prices, harmful byproducts emissions, etc. Realizing this, the U.S. stepped their first step out towards a carbon neutrality world by introducing their ambitious plan of net-zero emissions by 2050. Since then, the development of Renewable Energy has been strongly promoted in the U.S. Two most potential energies, solar and nuclear energy, are aggressively evolving and spreading across the U.S. Solar energy favors the society's needs by its lower cost and higher efficiency while the nuclear energy leads the RE (renewable energy) mix according to its huge potential. This article will introduce you to all the significant knowledge that you need to know in order to compare them and get conclusions. It's short but precise, advantages and disadvantages of each will be shown objectively and some subjective comparison in the end will enhance your thinking and help your understanding.

Keywords: Development prospects; nuclear; solar energy; U.S.

1. Introduction

Global energy demand is expected to continue to increase by 50% between 2018 and 2050 [1], which is largely resulted by the increasing rate of world energy consumption as shown in the graph below in recent years [2].



Fig. 1 Global energy demand between 1980 to 2005

Currently, fossil fuel is the only energy mix adopted by human beings to match this roaring demand. However, relying on this toxic energy source is neither permanent nor sustainable due to a great number of irreversible aftermaths that go with it. A significant part of which is caused by excessive emission of carbon dioxide. It is observed that the carbon emissions from fossil fuel use is steadily increasing at a rate of 1% per year [2], which directly contributes to global warming of our planet. The best alternative to meet this energy demand is Renewable energies. As all countries including the U.S. started to act, the renewable energy sector had been aggressively driven.

Among all of them, biomass energy is limited by the lack of land and water resources in the U.S.; wind is challenged by intermittency all the time, and the total capacity of class 4 and higher wind resources in the U.S. is only about 12 Terawatts (TW) (American wind Association, 1991). Compared to wind energy, although solar is intermittent as well, it's capable of producing and storing tens or

hundreds of TWs [3] with lower cost. Besides solar, the advantages of nuclear energy are also significant which contain both economic impact and environmental impact.

So, this article will address solar energy and nuclear energy’s current situations as well as their future trend. Purpose of the article is to compare these two most potential resources through evaluating existing evidence and research. Unlike lots of existing articles, this one has filtered an amount of information objectively that allows you to form a basic understanding of their current situations and developmental prospects.

2. Nuclear Energy

In the U.S., there is strong support for nuclear energy. In the United States, the directors of the ten Energy national laboratories under the Department of the energy of the United States released a statement saying, “there is a strong belief that nuclear energy needs to be a major and expanding part of the countries and the world’s energy portfolio” [1]. The United States Framework Convention on Climate Change’s Executive Secretary, however, stated that he has never seen a workable approach to combating climate change that does not involve nuclear energy [3]. Currently, nuclear energy’s situation is positive in the United States, they have the largest number of reactors (104) which are mostly operating reactors and those under construction are light-water reactors.

Two primary reasons that may enhance the development of nuclear energy are its roles in replacing oil and reducing CO₂ emission.

Environmentally, the advantage of nuclear power is huge compared to other energy resources. Nuclear energy plays a big role in reducing CO₂ emission. According to a scientific result concluded using the Toda and Yamaoto (1995) version of the Granger non-causality test [4], it has been discovered that while using renewable energy sources either little at all or not at all helps reduce CO₂ emissions, using nuclear energy does so [4]. The table below presents the results of the Granger causality test, and it is inferred that the use of nuclear energy contributes to a decrease in CO₂ emissions because the coefficient of the lagged nuclear energy consumption variable is negative. While renewable energy is the opposite. In this table, ***, ** and * denote significant levels at 1%, 5% and 10%, respectively.

Table 1. Granger causality test [4]

Direction of causality	χ^2 (Chi-squared)	p-value	Σ of the lagged coefficients
from ln Nt to ln Ct	7.075	0.070*	-0.046
from ln Ct to ln Nt	3.174	0.366	-0.186
from ln Rt to ln Ct	1.495	0.683	-0.032
from ln Ct to ln Rt	14.758	0.002***	0.541
from ln Yt to ln Ct	8.221	0.042**	0.142
from ln Ct to ln Yt	12.059	0.007***	0.299
from ln Rt to ln Nt	6.297	0.098*	0.396
from ln Nt to ln Rt	5.635	0.131	0.123
from ln Yt to ln Nt	5.381	0.146	0.265
from ln Nt to ln Yt	1.715	0.634	0.000
from ln Yt to ln Rt	8.289	0.040**	-0.331
from ln Rt to ln Yt	4.554	0.208	0.482

Economically, the cost of oil rose by two or three times around the world in recent years, because of that, export competitiveness is significantly lowered and cost of production rises. Though the United States is an energy independent country, our economic performance is still affected by it since fossil fuels provide 85% of the energy needs nowadays [5]. So, it is obvious to see that the main community focus of nuclear power generation is to produce electricity at a competitive price to avoid massive reliance on fossil fuel sources. Here is a multivariate nuclear energy equation based on available data and economic theory [5].

$$\ln NC_t = a + b \ln OP_t + c \ln OC_t + d \ln RY_t + e_t \quad (1)$$

NC represents nuclear energy consumption; op is real oil price; OC is oil consumption; RY is real GDP; e is an error term; and subscript t denotes the time [5]. Outcome of the equation is to show that nuclear energy is the most likely substitute for oil.

As the need for nuclear energy rises, suppliers will provide more affordable, more advanced reactor designs that increase efficiency and safety. A brief history of them listed below can demonstrate this pattern:

Generation I reactors were developed first; they are small but cost much and the Efficiency is low [6]. Generation II reactors were way more advanced than that of the first generation, they had higher efficiency while cost way less than the previous one [6].

If the public and community focus on nuclear power's development, these reactors will be upgraded faster, which will dramatically increase the efficiency of nuclear energy, a positive developing circle will be formed this way.

Nuclear energy also carries disadvantages as well. Radioactive waste is produced along the process, which is usually toxic and extremely harmful for human beings. One of the most catastrophic nuclear disasters, the Chernobyl disaster [7], keeps warning people about the downsides of nuclear energy. According to the records, 30,000 people perished in the Chernobyl accident, and over 2.5 million Ukrainians continue to suffer from the health effects of radioactive waste. [8].

Above all, nuclear energy does possess huge potential (roles in reducing CO₂ and replacing oil, new reactors, and promising developmental prospects) with certain drawbacks (Radioactive waste and disasters) to dominate the RE mix in the next couple of decades in the US.

3. Solar Energy

Solar energy, which is now the energy source with the fastest rate of growth, is another prominent renewable energy source in addition to nuclear energy. One of the world's top generators of solar energy has been the United States. The graph attached below has clearly listed four aspects of solar energy that will largely decide its future trend.

Technologies that are often used to generate solar power are PV, CSP, SHC, and Hybrid, each of them possesses its own advantages and is favored by different countries, as shown in fig.2. PV is currently the most popular and welcomed one in the U.S. Growth factors of Solar energy are all indicated in the graph. Combined with its market and price's trend, we can forecast the prospects of solar energy.

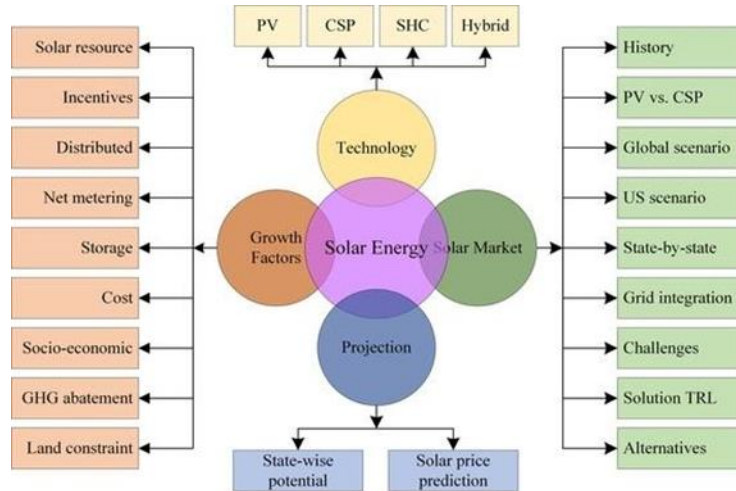


Fig. 2 Technologies used to generate solar power [9]

Two methods that we adopted to use for predicting solar energy’s prospects are Simulink and the Wright’s law, which accordingly are used for predicting the distribution and price of solar in the future.

Weighted hyperplanes for each state in the United States are used to simulate Simulink, and the outcome displays the future distribution of solar growth in each state. This will focus on the growth of solar instead of the total installations. More information on the growth of installations of solar energy can be seen in fig.3 [10]. Instead of putting them into a model, looking at a graph can be more direct. There are currently over 2 million solar PV installations in the United States (one of the most popular solar technologies), this is a new height in the U.S., and they are expected to grow even more in the following decades. “Our most recent projections indicated that by 2024, there will be one solar installation every minute on average,” stated Michelle Davis, a Senior Solar Analyst at Wood Mackenzie [9].

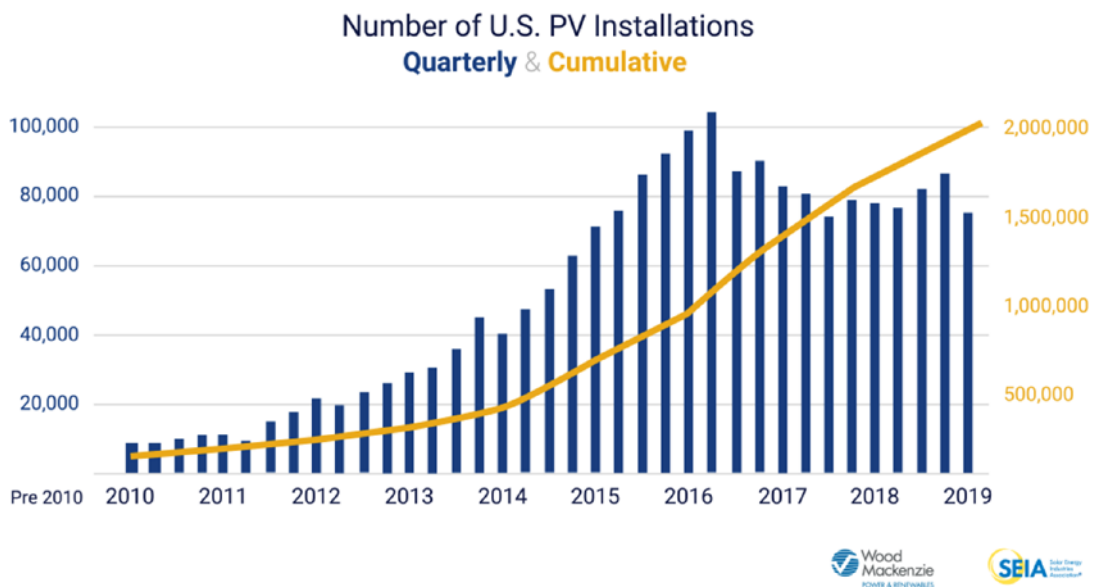


Fig. 3 Number of U.S. PV installations graph [10]

To predict the price of solar in the next decades, Wright’s Law was used. It indicates that each doubling of the cumulative production scale will lead to a stable percentage drop in technological costs. In the case of solar, for every doubling of cumulative production, the price of solar modules per watt of power falls by around 25%, as shown in fig.4.

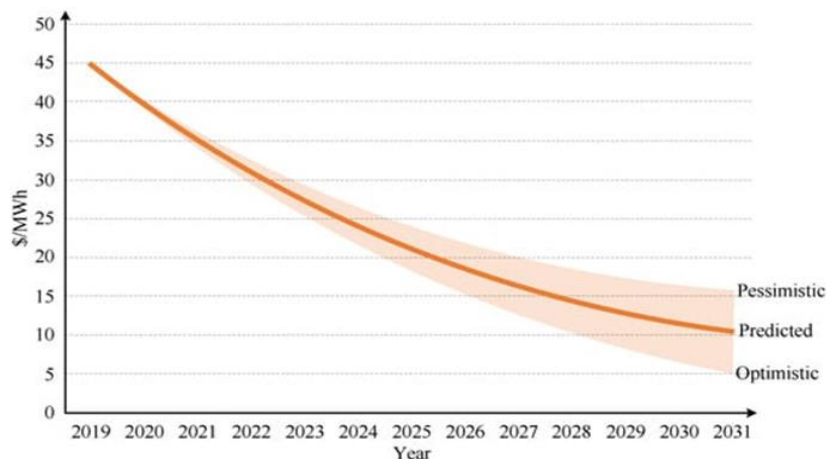


Fig. 4 The predicted price points of solar energy in the U.S. up to 2031 [4]

Wright’s Law functions exponentially, when it displays exponential growth, it displays an uphill straight line; when it displays an exponential decrease, it displays a downward line. [9]. Here is the graph drawn according to the calculation by Wright’s Law. We can clearly tell that the price is going to decrease dramatically in the next decade.

Despite all the advantages, some challenges still exist. For example, land requirements. To produce a considerable amount of energy, a large land area is required. And usually, it’s hard to give too much land for solar energy production. However, people are taking actions to meet the solution: many alternatives to large-scale solar plants are planning to be implemented.

In conclusion, solar power’s prospects are promising and limitless. With the decrease in price and the leap in installed capacity over the past decades, solar power has gained much more popularity around the world. As the challenge of intermittency met their solutions, and alternative applications of solar energy were discussed, an increasing number of people began to hold the view that solar energy does have the potential to become the most dominating energy source on the U.S.’s path to a net-zero emission economy.

4. Comparison

Above all, since the U.S.’s plan of achieving net-zero emissions is proposed, renewable energy’s development is promoted vastly. The prospects of it are bright and promising. Two dominant energy sources of RE are both competitive with fossil fuel energy in terms of both pricing and efficiency. Nuclear energy is a good climate change combater especially in fighting against CO₂, meanwhile has a lower reliance on oil; solar energy is more popular currently in the U.S. since they are safer and easier to plant. Although both possess huge potential to replace fossil fuels, nuclear energy is more likely to be the dominant one since it is way more exploitable than solar energy. However, the competition between them is not meaningful, our main mission is to stop the reliance on fossil fuels and build a net-zero emission not only for a country but for the world.

5. Conclusions

The paper presents several data-driven evidence of both energies that may lead to their fast development. Some theoretical evidence is also introduced with potential advantages and disadvantages. Furthermore, Wright’s Law has been used to forecast that the cost of solar technology in the United States will fall to \$10/MWh over the course of the next ten years. Besides, the disadvantages are also discussed objectively here. The outcome occurs that, in the next 30 years, following the U.S.’s net-zero emissions plan, nuclear energy may be a more dominant energy resource than solar energy because of its developability.

References

- [1] Petrescu FIT, Apicellar A, Kozaitis SP, et al. Environmental Protection through Nuclear Energy. *American Journal of Applied Sciences*, 2016, 13(9):941-946.
- [2] Cuttler Jerry M. and Pollycove Myron. NUCLEAR ENERGY AND HEALTH And the Benefits of Low-Dose Radiation Hormesis. *Dose-Response*, 2009, 7(1):52-89.
- [3] Fthenakis, Vasilis, Zweibel Ken. The Technical, Geographical, and Economic Feasibility for Solar Energy to Supply the Energy Needs of the US. *Energy Policy*, 2009, 37(2): 387–399.
- [4] Menyah, Kojo, and Yemane Wolde-Rufael. CO2 Emissions, Nuclear Energy, Renewable Energy and Economic Growth in the US. *Energy Policy*, 2010, 38(6): 2911–2915.
- [5] Lee, Chien-Chiang, and Yi-Bin Chiu. Nuclear Energy Consumption, Oil Prices, and Economic Growth: Evidence from Highly Industrialized Countries. *Energy Economics*, 2011, 33(2): 236–248.
- [6] Ahearne, John F. Prospects for Nuclear Energy. *Energy Economics*, 2011, 33(4): 572–580
- [7] Sreoshi Chatterjee. “Disadvantages of Nuclear Energy.” *Power World Analysis*. February 20, 2018. Retrieved on December 1, 2023. Retrieved from <http://www.powerworldanalysis.com/disadvantages-nuclear-energy/>
- [8] Tabassum Sanzana, Rahman Tanvin, Islam Ashraf UI, et al. Solar Energy in the United States: Development, Challenges and Future Prospects. *Energies*, 2021, 14(23): 8142.
- [9] “United States Surpasses 2 Million Solar Installations | SEIA.” SEIA, 2019, <https://www.seia.org/news/united-states-surpasses-2-million-solar-installations>.
- [10] Prăvălie, Remus, and Georgeta Bandoc. “Nuclear Energy: Between Global Electricity Demand, Worldwide Decarbonisation Imperativeness, and Planetary Environmental Implications.” *Journal of Environmental Management*, vol. 209, Mar. 2018, pp. 81–92, <https://doi.org/10.1016/j.jenvman.2017.12.043>. Accessed 10 Dec. 2019.