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Residential Use of Photovoltaic Panels and Their Implications on Regional Power Webs

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ABSTRACT

More and more families are starting to construct a whole solar energy system in their houses with photovoltaic panels and battery components. This research primarily focuses on how residential and affordable photovoltaic panels implanted on houses' roofs can create a better and more sustainable regional power web. This research mainly focuses on the beneficial effects of connecting the residential photovoltaic panels to the regional power web from a family perspective and a regional power web perspective. The aim of this research is to find the answer for how domestic and affordable photovoltaic panels can develop a better sustainable energy cycle among families and electricity companies. Through using the general electricity data in America with some calculations to find how much money photovoltaic panels can save, along with some existing case studies, the result of this research shows that residential photovoltaic panels may not only can bring the economic retributions through selling and inputting the produced and surplus electricity to the regional power web but also bring the increasingly stable and abundant regional power web.

Introduction

A Sustainable Regional Power Web Among Different Individual Families and Consumers

With the increasing need for sustainable energy sources, people are developing more clean energy and materializing it: solar energy is one of the energy sources with substantial potential. According to the United Nations, the rate at which the Earth intercepts solar energy is about 10,000 times greater than the rate at which humankind consumes energy (United Nations, n.d.). With the rapid increase of solar technology, people can even implant solar energy systems in their homes. By implanting the photovoltaic panels on the roof, a battery system in the house, and some sub-structures (Nema et al., 2009). Families can use the energy produced by the system to power the electrical devices in the home.

From a societal perspective, if families link the domestic solar energy panels to the regional power web, that also connects other electricity consumers. Like other energy inputs (i.e., fossil fuel), photovoltaic panels can constantly provide electricity for other consumers. The regional power web can become more stable and abundant with another solid and constant energy input. From an economic perspective, during this process, since the owner of the regional power web, the government usually needs to pay money to buy the electricity input into the power web from the domestic photovoltaic panels. Then, the families will receive the money and finally, after a long period of transferring electricity into the regional power web, they may even retrieve the initial investment in buying the solar energy system (Bouly de Lesdain, 2015). Moreover, after this, the solar energy system will start to earn money for the family.

To conclude, while families are installing domestic photovoltaic panels on their houses' roofs, these panels benefit families since they can provide electricity for domestic usage and earn money. In addition, they also are beneficial for the regional power web stability and abundance.

Literature Review

Not Only Electricity: An Additional Output

Domestic photovoltaic panels may provide electricity, known as the one and only energy output from the panels. However, there is an additional output: while the photovoltaic panels harness the solar energy from the sun, correspondingly, thermal energy and heat are spontaneously produced. Researchers use the waste heat released by the photovoltaic panels to generate a comfortable temperature for the house, especially during the winter. To materialize this idea, a PV/T system is required to be implemented in solar energy systems. This system has shown its potential not only theoretically but also practically. In reality, researchers constructed the PV/T system linked with photovoltaic panels into the solar energy system, in which the panels were scattered across the globe. After a period of the experiment, these solar energy systems show high potential in providing constant hot water, generating warm temperatures, and still having a sufficient electricity production rate (Kalogirou & Tripanagnostopoulos, 2006). From this example, researchers found that solar energy systems have various and different usages other than only providing electricity. Furthermore, PV/T system is only a tiny enhancement in solar energy technologies. While the modern world technologies are evolving quickly, more and more new solar energy technologies, like PV/T system, will be produced. This makes people start to be concerned on the potential high prices when purchasing the photovoltaic panels.

Solar Energy Systems Cost: Keep Declining

Currently, more and more companies and families are using solar energy as a primary or alternative energy source to generate power. Sometimes, people are concerned about the high investment of a complete solar energy production and storage system. However, nowadays, according to figure 1 below, the prices of implanting a solar energy system, including the electricity manufacture and storage component, are decreasing rapidly (The National Renewable Energy Laboratory, 2021). With a lower price to purchase, more families will construct solar energy systems in their houses. Resultingly, with more photovoltaic panels connected to the regional power web, its stability and abundance can increase at a fast rate, corresponding to a decrement in purchasing a solar energy system. With the increasing number of residential photovoltaic panels installations, nearly all are able to connect to a regional power web. However, not all photovoltaic panel owners were willing to form a connection between the panels and the regional power web.

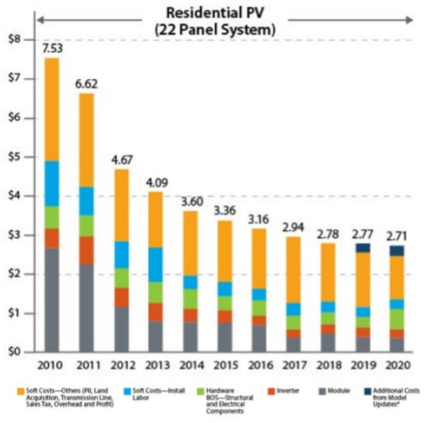

Figure 1. The Change in Costs of Purchasing a Solar Energy System from 2010 to 2020

Potentials are Wasted: Ununited Individual Solar Energy Systems

Solar energy systems have been widely applied and constructed. Researchers in Standford's DeepSolar Project suggest that over 1.47 million photovoltaic panels are settled across the 48 states in America (Wang et al., 2022). "Standardized residential photovoltaic panels on the market are quoted to generate averagely between 250 and 400 watts an hour" (Lumennow, 2021). In the U.S., "with analysts predicting more than 19 gigawatts of total capacity installed" (Atasu et al., 2022), the enormous potential of the photovoltaic panels can be materialized by uniting them into a cell. Researchers in Canada examined the feasibility of connecting the individual and residential solar to the distribution network, which was identical to a regional power web, after using a "single-phase inverter" and "three-phase transformer" to test the overall manifestation (e.g., temperatures) after the connection under diverse conditions, they finally proved that it was possible to form a connection among the domestic solar energy systems and the regional power web (Awadallah et al., 2015).

Result

Effective and Economic Electricity Generation for Families

Solar energy systems can effectively, economically, and constantly provide electricity for families' internal electric systems that may contain the A.C.s, refrigerators, lights, etc. According to table 1 in Appendix, families are constantly benefitted from the installations of the residential solar energy system in America. First, it can generate a substantial amount of electricity. Take a 4kW photovoltaic panel system as an example. It can generate over 2850 kWh per year (Ecogenius, 2022). With such a significant amount of additional electricity, families can make use of the electricity and finally decrease the electricity use cost. Second, it can increase the home's internal electric system's stability. With a constant electricity input from the photovoltaic panels stored in a battery or multiple batteries connected to the internal electric system, even though the house has encountered an emergency, with no electricity input from the external regional power web, the electrical devices in the system can still work correctly for an extended period with the electricity input from the batteries. To conclude, residential solar energy systems in families' houses can economically and steadily provide electricity for them. With such a tremendous amount of electricity, sometimes families need help to use them completely.

Surplus Electricity for Regional Power Web

Not all electricity produced by photovoltaic panels will be used by the family all the time. Surplus electricity produced by photovoltaic panels can be inputted into the regional power web and increase its abundance and stability correspondingly.

The regional power web's abundance can increase with an increasing volume of electricity. Considering a phenomenon, people may go on vacation for several days, weeks, or even months. Since families will not stay in the house during the vacation, there will be no electricity consumption. Even though there is no energy consumption, the sun will not stop shining, and the photovoltaic panels will keep generating electricity constantly. At this time, the electricity produced by photovoltaic panels will become useless and wasted if no one uses it. Considering table 1 in Appendix, now, the electricity consumption of a user becomes zero, and all electricity produced by photovoltaic panels has nowhere to go. Nevertheless, there is now a possible place for this surplus electricity: the regional power web. By establishing the connection between families and the regional power web, surplus electricity can be transferred into the web and increase its abundance with more electricity.

The stability of the regional power web can be enhanced with many scattered and widespread energy inputs: the photovoltaic panels that are connected to the web. According to the statistics from The Roundup, over 3.2 million

U.S. homes have installed photovoltaic panels. With such a significant number of constant electricity additional inputs, the regional power web's dependency on external inputs may decrease correspondingly. The external inputs may include the electricity generated by another city's power plants. With a lower dependency on external electricity inputs, the stability of the regional power web may increase. In September 2022, a hurricane hit America, causing massive damage in Florida. This disaster directly made over 2.6 million residential customers have no power to use. However, a town in Florida called Babcock Ranch was known as "America's first solar-powered town." The regional power web of Babcock Ranch was composed of more than 700000 individual panels installed in the Babcock Ranch's residents' houses. Moreover, these panels could constantly input electricity into the regional power web for other customers to use when necessary.

Finally, with the increasing volume of electricity being inputted into the regional power web, the abundance and stability of the power web increase correspondingly. Inputting the electricity into the regional power web is not only beneficial for other customers in the power web, but also beneficial for families who input the electricity into the power web (CBS, 2022).

Additional Income for Families

Families can gain income when inputting electricity into the regional power web. The organizer of a regional power web would usually be the local government, which will sell the electricity in the power web to the customers in the power web. With a solar energy system installed in a family's house, this family can be both a consumer and a producer. The family will consume the electricity from the power web when electricity produced by photovoltaic panels is not enough for residential usage. Moreover, the family will produce electricity for the power web when it cannot use all the electricity produced by the photovoltaic panels. When consuming electricity, the family costs money.

Furthermore, when producing the electricity, the family earns money from "selling" the electricity. In California, USA, there is a Net Energy Metering policy (NEM). This policy allows the families to connect their photovoltaic panels to the regional power web and "receive a financial credit on their electric bills for any surplus energy fed back to their utility." This means that when the family inputs the electricity into the regional power web, and after other consumers have used the input electricity, the government will decrease the money on their electric bills. In other words, this directly leads to additional financial income for the families (California Public Utilities Commission).

Discussion

The findings of this research are significant because they provide the world with another point of view or potential business from simply using photovoltaic panels to generate electricity for own residential usage. Imagine purchasing a photovoltaic panel, and after people have retrieved the initial cost in five or ten years, people then start to make money.

There are several limitations to this paper. One of the limitations is that, due to the difficulties when finding global data, small parts of this research primarily use the data and facts from America as pieces of evidence. These limited data and facts may lead to defects in the evidence since this research paper focuses on a worldwide view. Another limitation is that not all governments would allow individual photovoltaic panels to join the regional power web due to particular concerns. The policies from the government may lead to a total ban on the connection of photovoltaic panels to the regional power web. These two limitations may limit this research paper's materiality and enforceability.

Conclusion

Residential photovoltaic panels can promote a better and more sustainable regional power web among different families through a substantial volume of electricity generated by photovoltaic panels for families' internal electric system usages and external regional power web inputs. Families can use their photovoltaic panels to generate and input electricity into the regional power web, but they also can retrieve the electricity from the power web when needed. A family acts as an electricity producer and consumer, enabling regional power webs worldwide to achieve sustainability.

Table 1. The Electricity Consumption Related Information in America (Year 2021)

	Basic Information			Electricity Related Information			
State Name[*]	*Consumption Type*	*Sales of the Electricity*	*Ultimate Customers*	*Electricity Consumption per User*	*Electricity Price*	*Estimate Cost with no Solar Energy*	*Estimate Cost with Solar Energy Input*[**]
		million kWh	*families*	*kWh*	*dollar/kWh*	*dollars*	*dollars*
CA	Residential	90570.94502	14015328	6462.277945	0.1965	1269.83762	560.02500
IN	Residential	33731.03139	2936170	11488.10573	0.1036	1190.16775	295.25999
FL	Residential	129875.9699	9978587	13015.46701	0.1067	1388.75033	304.095
DE	Residential	5164.71148	452923	11403.06736	0.1050	1197.32207	299.24999
RI	Residential	3131.89181	444259	7049.698059	0.1844	1299.96432	525.53999
PA	Residential	56029.3498	5487230	10210.86227	0.0997	1018.02297	284.14500
NY	Residential	52389.06094	7356528	7121.438393	0.1611	1147.26373	459.13500
NM	Residential	7153.07766	906465	7891.179097	0.0979	772.546434	279.01500
MS	Residential	18750.79681	1333159	14064.9366	0.0950	1336.16898	270.75000
MI	Residential	35764.24436	4474204	7993.431761	0.1293	1033.55073	368.50500
CO	Residential	20815.2327	2418949	8605.072988	0.1090	937.952956	310.65000

Note: [*] This column includes the abbreviation of the states in America.

[**] This column is calculated by the function below: (To see the parameters' representation, please refer to **table 2**).

$$V_1 = V_2 - P(E_1 - E_2)$$

Statistical data is retrieved from U.S. Energy Information Administration (EIA).

Symbol	Description
V_1	Estimate Cost with Solar Energy Input
V_2	Estimate Cost with no Solar Energy
E_1	Electricity Consumption Volume per User
E_2	Electricity Volume Produced by Solar Energy System
P	Electricity Price

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