Is the Future Solar Powered?

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INTRODUCTION

In the past decade, solar power has become a rapidly developing method of renewable energy. In recent years solar technology cost has reduced significantly- providing accessibility to a wider array of potential consumers, including those outside of the developed world (Renewable Resources Co, 2016). Prior to the push for renewable energy sources, fossil fuels were widely used. There is evidence of fossil fuel use as early as 4000BC China, with the reported use of a form of coal known as lignite (Ritchie & Roser, 2020). The 7th century BC was the first period in which humans utilized solar energy, however, it was not until 1954 that photovoltaic technology was developed (U.S. Department of Energy, n.d.). Since then, the industry has continued to develop and verge into a consumer-based market space, with the industry expected to more than double in the next six years (Hariharan & Prasad, 2019). Most of this growth is driven by the demand for cleaner energy sources, as the effects of global warming becomes an issue with increasing concern and immanence (Hariharan & Prasad, 2019). American politician and environmentalist Al Gore has taken a firm stand for the use of Solar power as a mass source of renewable energy. He holds that earth's yearly energy needs fall onto Earth's surface every 40 minutes in the form of sunlight (Maly, 2015). In addition to solar power, there currently exist other forms of renewable energy- such as hydropower, wind, and geothermal energy sources. This paper will discuss what solar power is, how it is being used today and in the near future, benefits, as well as the disadvantages, and a comparison to other forms of renewable energy to determine if solar power is the among the best choices for renewable energy sources.

WHAT IS SOLAR ENERGY

Arguably the most abundant source of energy available on the planet, the suns' solar radiation kickstarts everything from food production to the electric vehicles we drive. Solar energy should

not be thought of in a linear fashion, but rather as a spectrum, as it can be broken apart to harness the sun's radiation in three different ways: thermal, electrical, and biofuel.

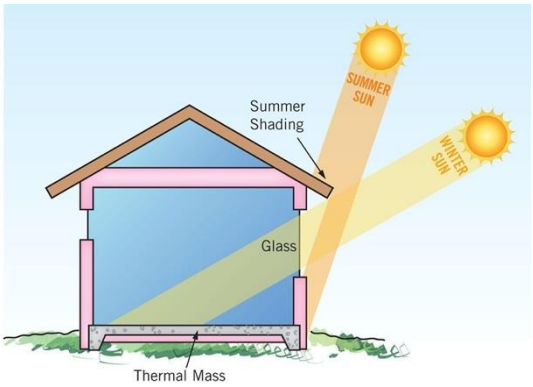

Figure 1: Eco Design Advisor. (n.d.). Insulation Efficiently working with the sun. [Online image]. Retrieved from https://www.ecodesignadvisor.org.nz/passive-solar-design/

Thermal energy from the sun is attained in two basic ways, passive and thermal conductivity. As shown in Figure 1, a house can utilize the positive benefits of passive solar heating by allowing the sun's rays to penetrate the house through windows and heat the surrounding air. Although an environmentally and economically effective way to heat a home, this option is impractical and unrealistic in the northern, and colder, climates. The alternative method of thermal solar energy uses the suns' radiation energy to heat thermal conductive materials in order to retain heat (Eco Design Advisor, n.d.). For example, a vehicle hood will get hot after sitting in the sun due to the high thermal conductive nature of the material. Additionally, a common system seen in houses is the use of pipes filled with water or other high heat-capacity liquids, which are then laid out across a roof and fed back into the home for heating (Eco Design Advisor, n.d.). This process is effective in transporting thermal energy throughout a household; however, due to the complicated structure of the system, it is prone to costly repairs and maintenance (Eco Design Advisor, n.d.). These two basic examples of thermal energy demonstrate that the sun's solar radiation can be harnessed in a variety of manners.

When we talk about solar energy, the most common association is solar panels and the production of electricity. Although solar panels have unparalleled qualities, when it comes to production, integration, and simplicity, there are some key things to keep in mind. The inner

workings of a solar panel or solar cells are not complicated, but showcase the complications that arise as a result of basic issues, such as scalability and demand.

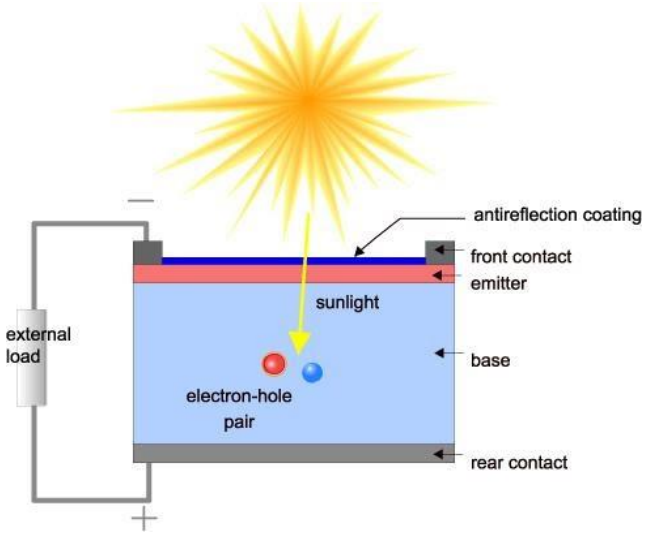

Figure 2: PV Education. (2019). Cross-section of a solar cell. [Online image]. Retrieved from https://www.pveducation.org/pvcdrom/solar-cell-operation/solar-cell-structure.

Solar cells commonly contain two types of silicon, p-type and n-type, sandwiched in a non-conductive housing (Woodford, 2019). When a photon enters from the top of the cell and collides with the silicon atoms, an electron breaks loose, as seen in Figure 2 (2019). Due to the potential difference between the positively and negatively charged silicon, an electrical charge is produced (2019). This process is repeated time and time again in multiple cells throughout a solar panel (2019). This seems simple and effective, which it is, but with anything that seems too good to be true, an issue arises in regards to efficiency between energy produced and energy demanded. However, this gap is being shortened, with efficiency having increased by 34% in the last 65 years (Becker, 2019). Currently, there is a disparity between solar energy production and demand, which leads to our reliance on fossil fuels.

There is little disagreement about the positive environmental impact of solar energy in our modern-day society, particularly when compared to the fossil fuel alternative. However, it begs the question- why do we not see solar cells lining sidewalks and rooftops? Although highly efficient in many ways, solar energy is limited by one factor- the sun. Although this is not a concern in areas receiving year-round sunlight (such as equatorial countries), in places such as

our very own, Victoria, BC, the presence of sunlight in the winter months is little to none (Weather and Climate, n.d.). Without consistent solar energy, our systems of conduction and photovoltaic properties fall apart. The appeal of fossil fuels increases, as we see the ease of implication, expedience, and price towards the general consumer. It would seem foolish to compare the environmental impacts of solar energy and fossil fuels. However, with a closer look at the future of solar energy, we can see a growing list of potential draw-backs.

There is a future for solar, however, with land and financial considerations playing a major role in the development of the industry, the idea of mass solar farms and individual investment seem out of reach for now.

HOW IS SOLAR ENERGY BEING USED TODAY

Within the consumer market space, the use of solar technology has continued to grow, with companies such as IKEA and Tesla helping to reduce their carbon footprint. Using the slogan, “The solution rises every morning. So let's rise to the challenge together,” (IKEA, n.d.), IKEA is making an effort to use Solar Energy as a means to fight climate change To tackle this issue, they have over 750,000 solar panels on their buildings and stores (IKEA, n.d.). Brendan Seale, Head of Sustainability for IKEA Canada, made the following statement regarding IKEA’s efforts to use renewable energy: “These investments support our objectives to manage energy costs effectively, reduce our emissions, and achieve energy independence by 2020.” (IKEA, n.d.). Globally, the IKEA group plans to produce more renewable energy than the total energy consumed in all operations worldwide (IKEA, n.d.). IKEA Canada has been named as one of Canada’s Greenest Employers for 10 consecutive years for its commitment to using solar energy as a substitute (IKEA, n.d.).

Another major company is making an effort to use solar energy as an alternative to non-renewable options. Tesla, the automotive and energy company lead by Elon Musk, now has an option for consumers to purchase a product, known as Solarglass, for the roof of both homes and vehicles. Solarglass replaces an existing roof with solar panels that can power homes with the energy the consumer produces (Tesla, n.d.). Tesla claims that its roof provides the lowest cost per watt of any national solar panel provider and is comparable in price to a typical roof

with solar panels (Tesla, n.d.). Another area where Tesla is using Solar Energy is with its new Cybertruck, which Tesla has stated will have the option for a solar panel system with the potential to generate enough energy to travel up to 15 extra miles per day (Olivia, 2019). In a tweet posted on November 22, 2019, Elon Musk shared his vision of having fold-out solar wings that would generate 30 to 40 miles per day (Olivia, 2019).

Usually, solar panels are spread flat on a rooftop, or other surfaces that keep the cells pointed straight at the sun. However, more recently, a team at the Massachusetts Institute of Technology (MIT) has invented a new approach to the way the solar panels are arranged. The researchers at MIT have created a "tower" that extends the solar panels upwards in a 3-D configuration (Chandler, 2012). Interestingly enough, the result showed that the 3-D structures produce two to twenty times more energy than that of a panel that is situated flat on a rooftop or surface (Chandler, 2012). This is possible because it can collect additional sunlight during mornings, evenings, and winter, when the sun is closer to the horizon, something that typical solar panel configurations are unable to do as effectively (Chandler, 2012). This 3-D structure is a very interesting concept that should be closely watched over the next few years, as it has the potential to be a more efficient strategy when it comes to collecting solar energy.

Finally, the last company we will briefly explore is Toyota, who has been making steps further into the renewable energy industry, as they strive to create a solely solar-powered vehicle (Ortega & Moynihan, 2019). Although it is still in the early stages, Toyota engineers have fitted solar panels to the hood, roof, rear window and spoiler in an effort to see how much energy the sun can produce (Buckland, 2019). The electricity from the panels goes directly to the drive battery, so the vehicle can charge while moving as well as when parked (Buckland, 2019). Current tests suggest that the car is able to drive for up to 56 kilometres before needing to be charged (Buckland, 2019). However, the performance does drop off if it is either too hot or cloudy (Buckland, 2019). There's no denying that the Toyota solar-powered car is still in the early stages of development, but it may be something to look out for in the future.

ADVANTAGES OF SOLAR ENERGY

Solar power is a renewable energy in a sense, that converts the sunlight into a usable energy form and emits no greenhouse gas (USEPA, n.d.). This zero-emission ultimately helps in

lowering the rate of global warming. According to research done by Srinivasan Chinnamani (2014), a typical home solar photovoltaic could save over a tonne of carbon dioxide a year alone, with the potential of saving more than 30 tonnes over a PV's lifetime. To look at the broader spectrum of greenhouse gas emissions we can save, we can refer to research which calculated the percentages of all kinds of greenhouse gas emissions saved when using solar water heating system with electricity backup (figure 3). As shown in figure 3, the solar water heating system, with electricity backup, saves about 80% of greenhouse gas that a conventional system would emit. The research further investigated other heating systems such as those using both electricity and diesel backup, and overall, all systems which used solar energy demonstrated significantly more environmentally friendly results in terms of a reduction in greenhouse gas emissions, in comparison to a conventional heating system (Kalogirou, 2003).

Emissions	Units	Conventional	Solar system	Savings (%)	Equation	R^2-value
Carbon dioxide (CO_2)	tons/year	1.982	0.40	79.8	$y=0.0009x+0.1635$	0.9994
Carbon monoxide (CO)	g/year	496	100	79.8	$y=0.2173x+40.86$	0.9995
Nitrogen oxides (NO_x)	g/year	74	15	79.8	$y=0.0328x+5.9127$	0.9996
Nitrous oxide (N_2O)	g/year	7	2	79.8	$y=0.0026x+1.3075$	0.9892
Methane (CH_4)	g/year	12	3	79.8	$y=0.0054x+0.9851$	0.9988
Hydrocarbons	g/year	50	10	79.8	$y=0.0219x+4.0365$	0.9992
Sulfur dioxide (SO_2)	g/year	743	150	79.8	$y=0.3266x+61.042$	0.9994
Dust	g/year	248	50	79.8	$y=0.1093x+20.182$	0.9992
Savings in GHG	%	–	–	79.8	–	–

Note: In equations, y represents pollutant emission and x represents system annual energy requirements in kW h.

Figure 3: Environmental impact of solar water heating system with electricity backup (Kalogirou, 2003).

Besides solar energy being unequivocally more environmentally friendly than other conventional energy systems that use fossil fuels as feedstocks, it is economically more stable. The installation cost of solar PV has dropped significantly over the last couple of years, and this trend is expected to continue as technology advances. Although installation fees would vary between companies and their products, the costs are reasonably proportional to how much

energy and greenhouse gas emissions each installation can save (Chinnammai, 2014). Furthermore, the installation cost is a one-time concern.

Often, the overall cost of maintenance is brought into question. In British Columbia (BC), a typical 1kW solar PV system would have a lifetime of 25 years while producing 1,200 kWh/year. This is considering an industry average solar efficiency degradation rate of 0.5% per year (BC Hydro, n.d.). During a 25 year period, the probability of a solar panel being damaged is relatively low as it is usually installed on the roof of a building. In the rare case that it would become damaged, the repair fee of a solar panel ranges from $186 to $1,101 depending on the severity of the damage, which is still considerably lower than the repair cost of any other energy system (HomeAdvisor, 2020).

Finally, the Canadian government has developed incentive programs specifically for those who have installed solar PV on their houses. The Canadian energy market is primarily regulated at the provincial level; therefore, each province has a separate solar market and its electricity rates. For example, in BC, there are three supportive programs for solar PV: BC Hydro Net Metering, Fortis BC net metering, and Standing offer program. BC Net metering was designed by BC Hydro to help its commercial and residential customers to generate their own clean energy. The excess energy generated from customers' solar PV is credited to offset their future hydro bills. At each customer's anniversary date, excess credits are paid by BC Hydro to its customer in rates of 9.99 cents/kWh. Fortis BC net metering is an additional electric utility which serves a similar purpose as of BC Hydro, however, with a limit to the power generating per electric unit at 50 kW, the customers' excess credit is paid every March 31st of each year. Lastly, Standing offer programs are designed by BC Hydro specifically for electric units generating from 100 kW to 15 mW to determine the price which BC Hydro must pay to its customers with a base price determined by the point of injection, as seen in Figure 4 (Sow *et al*., 2019).

Region of POI	Base Price (2016 ¢/kWh)
Vancouver Island	11.001
Lower Mainland	11.156
Kelly/Nicola	10.439
Central Interior	10.680
Peace Region	10.206
North Coast	10.347
South Interior	10.650
East Kootenay	10.994

Figure 4: Standing offer program base prices on POI in B.C. (Sow et al., 2019).

Overall, solar energy can cut a significant amount of greenhouse gas emissions in its process of converting sunlight into energy relative to other conventional sources. Further, Government incentives increase the potential economic sustainability of these technologies. Therefore, solar energy may prove to be one of the most important conventional energy sources for the future.

DISADVANTAGES OF SOLAR ENERGY

Despite the many benefits of solar power, this renewable energy source also comes with a number of disadvantages. In the case of residential solar power, there are some significant drawbacks to consider. For one, homeowners with rooftop solar panels should note the potential hassle that may arise when routine maintenance and repairs of the underlying roof are required (Gromicko, n.d.). Perhaps the most obvious drawback is that solar energy can only be harvested during daylight hours. To address this concern, recent technological advances have led to the production of innovative power storage solutions- like Tesla's Powerwall battery (Tesla, n.d.). By saving excess energy harvested during daylight hours, power needs may still be met at night and on cloudy days (Tesla, n.d.). However, power storage batteries are expensive, take up space, and are not very ubiquitous (Gromicko, n.d.).

Cost is an important consideration for homeowners. Despite prices having dropped significantly over the years, initial investment costs remain high. Even in areas where regional or federal subsidies are offered, the up-front expenses can be prohibitive. In addition to

purchasing solar panels, homeowners must also consider the expense of other required materials such as an inverter, wiring and mounting hardware. Additionally, there are fees associated with permits, installation, inspection, and maintenance, etc. (Renewable Resources Co, 2016). Further, the cost of power storage batteries for a home can add tens of thousands of dollars to the tab (Renewable Resources Co, 2016). Alternatively, the home may remain connected to the grid and buy power from it at night. Remaining connected comes with its own set of potential concerns.

Once a residential solar power system is installed, homeowners are often required to await approval from their local electric utility provider before being permitted to switch on their panels. This can be a lengthy process. As seen in Hawaii (where solar accounts for 12% of electric utility users), when too many homeowners switch to solar power it can pose a huge threat to the safety and functionality of the gird. Most regions rely on power grids that were designed many years ago and without consideration for the 2-way power flow that occurs when excess solar energy is sent from homes back through the grid (Fairley, 2019).

Before installing rooftop panels it is suggested that homeowners do a cost-back calculation to determine how many years it will take to recoup initial investments. However, it has become increasingly difficult to estimate cost-back time periods as the electric power industry evolves in response to the growing solar movement (Hernandez, 2016). For instance, the rising popularity of rooftop solar power in Nevada has led to a huge rate and fee increases specifically targeted at solar users (Hernandez, 2016). While homeowners have long been able to sell excess power generated by their roof-top units back to the main grid for retail value, utility companies in areas like Nevada and Hawaii are slashing their buy-back rates by as much as two-thirds (Hernandez, 2016). Some argue that it is unfair for residential solar energy users to benefit from evening use of the grid without contributing to the costs associated with developing and maintaining it.

Solar energy is not as efficient as some might expect. The most efficient solar panels on the market only convert about 22% of their available energy into power (Renewable Resources Co, 2016). Efficiency may increase as technology advances; however, solar cells will never reach 100% efficiency due to the 2nd law of thermodynamics. Latitude can further impact efficacy;

panels located at a greater distance from the equator will experience a more significant solar disadvantage. Habitually cloudy/foggy regions will also see decreased efficiency. The shape of a panel has a significant impact on efficiency. The common flat panel can reduce potential efficacy by up to 38 percent due to energy reflectance alone ("Solar Panel Efficiency," n.d.). Solar Power is also associated with environmental impacts. Solar fields take up a great deal of space- space that will no longer be available for growing food, animal grazing, or as a habitat for wildlife ("Environmental Impacts of Solar Power," 2013). The mining of materials used in solar panel production also impacts the environment. The panels themselves contain a number of toxic and potentially hazardous materials such as cadmium, lead, gallium arsenide, copper-indium-gallium-diselenide, hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone ("Environmental Impacts of Solar Power," 2013; Gromicko, n.d.; Renewable Resources Co, 2016). Some countries (like the United States and Canada) require that manufacturers ensure proper recycling and disposal of these substances, however, other countries (like Malaysia, China, Taiwan, and the Philippines where over half of the photovoltaics are manufactured) do not follow the same strict regulations (Mulvaney, 2014). Improper disposal can pollute water, air, and soil resulting in devastating outcomes (Renewable Resources Co, 2016). Solar fields pose a significant risk to avian wildlife who are often drawn to solar fields- mistaking the reflective surface of solar panels for a body of water. Flying over these fields can result in death due to the ignition of birds' feathers midair (Upton, 2014).

Other types of Renewable energy

Solar energy is one of the most well-known renewable power technologies, but it is not the only one. There are many other types of renewable energy sources that can be beneficial to the environment and society as a whole. Renewable energy sources, in general, offer many benefits; they reduce the need for imported fuels and create many jobs without contributing to greenhouse gas emissions (Environmental protection agency, n.d.). Wind energy, for example, is another green energy source that is worth comparing. Wind power may, in fact, prove more efficient than solar energy; standard solar panel efficiency is roughly 15-20%, whereas wind power is estimated as reaching nearly 60% efficiency (Sendy, 2020). Additionally, wind power is not reliant on the sun, and therefore has the potential to generate

energy for 24 hours a day (Sendy, 2020). It should be noted, however, that wind is not always as widely available as sunlight in many areas of the world. When comparing costs, wind and solar are relatively equal, except that over time wind turbines can become costlier in terms of maintenance (Sendy, 2020). Wind turbines also pose a number of problems, in terms of wind direction and strength and noise emission (Sendy, 2020).

Geothermal energy is another type of energy with promising potential due to the massive amount of heat stored in the Earth's core. It is considered to be environmentally friendly, and in contrast with solar and wind, geothermal energy provides a stable and consistent source of energy ("Geothermal Energy Pros and Cons," n.d.). Geothermal energy outcompetes solar energy in colder regions due to increased heating needs ("Geothermal Energy Pros and Cons," n.d.). However, when it comes to installation costs and effort, geothermal energy is much more expensive and difficult to set up "Geothermal Energy Pros and Cons," (n.d.).

Nuclear energy is already an important source of energy today; in 2008, 20% of the electricity in the United States was generated by the nuclear power sector ("Nuclear Energy Pros and Cons," n.d.). Cost and time are two major factors when comparing nuclear energy to solar energy. Nuclear power takes much longer to build, and is roughly 10x more expensive ("Solar vs. Nuclear," 2019). This may be a disadvantage that nuclear energy is not able to overcome. Many studies say that solar energy will always be more cost and time effective than nuclear energy, even when considering the capacity for energy production that nuclear power has ("Solar vs. Nuclear," 2019).

Conclusion

Overall, solar power has the potential to be a widely accessible renewable energy source. To summarize, solar power works by absorbing sunlight, with the use of photovoltaic cells, once inside the cell, a current is created as a silicon layer excites the electron, creating a current that is then used to make a circuit. However, although it has little to no greenhouse gas emissions, the full use of the sun's energy is still a long way away, and many other sources of renewable energy are already much more efficient. Regardless, solar energy still holds a place within the consumer and industrial market, as it is one of the only portable renewable energy

sources. Furthermore, its use to power a home does not require individuals to live in particular jurisdiction, unlike other forms of renewable energy such as nuclear or hydropower. In the future, we hope to see the use of solar power continuing to expand, as it has the potential to make a large impact in our society. In conclusion, although the use of solar power has many positives, currently, many would argue that the negatives are too significant at this time, however, the future looks bright for solar powers growing presence within the renewable energy industry.

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