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The Viability of Solar Implementation

Alternative energy sources have been studied and critiqued at length since the first hydrogen fuel cell was developed by William Robert Grove in 1838. After the eruption of coal usage in European ore mines, scientists continued to research novel and perhaps more convenient ways to generate energy to power the world's ever-expanding arsenal of technologies. Following the development of the fuel cell, emergent sources of energy were discovered in the form of windmills, solar power systems, hydro-electric stations, etc. However, all of these paled in comparison to the accessibility and efficiency that coal and other fossil fuel-based systems provided. By the early 1900s, fossil fuel power had become an integral part of western society, which arguably enabled large-scale conflicts like the World Wars to even happen. At this point, there was no immediate reason for a coal alternative to exist.

One of the most fundamental issues with alternative energy sources is their public perceptions immediately following their introductions. Nuclear energy has faced public backlash primarily due to the connotation associated with 'nuclear' along with high capital costs associated with the construction of power plants. Novel renewable sources have also been rejected in more recent years, like the newly suggested smart grid, for concerns over "security, privacy, potential health impacts" (Boudet 1). Concerns such as these arguably stem from the fear of a radical upheaval of a society which has depended on coal for decades. However, one technology in particular has averted the ire of the public which has been developed and touted as an upper-tier alternative, clean energy source: solar power.

Researchers have utilized the familiarity hypothesis to measure how trustworthy the public is of the major alternative energy sources. This model tests for “ideological predispositions, environmental and altruistic values, cultural worldviews, media portrayals, and elite cues” to measure the extent to which an individual’s knowledge of a technology or discovery stems from illogical, self-prescribed sources. Responses garnered from independent studies on these sources yielded that “relative advantage, compatibility, simplicity, trialability, and observability” are factors favoring the mass-implementation of solar panels. While it has been found that people would like to change their lifestyles to an extent to accommodate for environmental issues (Boudet 4), these wishes are often squashed by high up-front costs and long payback periods in the form of tax credits or some other alternative. Here, I will review policies concerning the implementation of utility and domestic solar panels and the extent to which government incentives may be necessary to encourage the public to buy-in on the solar panel industry.

Cost-breakdowns of large-scale solar projects in the UAE have been performed as the UAE seeks to transition away from an oil-centric economy. A low price was achieved in the projections primarily due to two factors: “the plummeting costs of solar panels and the reduced costs of financing” (Apostoleris 1). Project developers in the UAE were often found to be state-connected corporations that were backed by the government. The financing provided by these companies was made possible by large loans covering “70-80% of the project costs with low interest rates.” With the requisite amount of government support in the form of direct investment or low-interest loans, it is possible to appease willing companies enough to partake in the risky proposition of financing large-scale solar projects. The researchers from this group point out that electricity from photovoltaic cells was found to be cheaper than electricity powered by coal in sunny regions of the world. They assert that if financial costs are low, they have found that selling electricity at market price is more than enough to meet the expenses accrued from the initial investment.

The primary motivators in the sharp decrease in electricity provided by photovoltaic cells compared to that provided by coal in the UAE can be explained through falling prices in hardware, tax incentives and the sheer amount of energy that is able to be generated in the sunbathed UAE. With the emergence of these cost breakdowns, more and more Middle Eastern nations are becoming interested in the implementation of large-scale utility solar projects in the coming future (Apostoleris #2 1). The realization of large reductions in capital and operating expenses can be attributed to the following: "forward-bidding of expected lower future hardware prices… low construction and operation and maintenance labor costs… scaling up plants [from the megawatt to gigawatt scale], extended PPA (power purchase agreement) term to 25 years, and favorable financial terms" (2).

The possibility of diving below a cost per unit energy of 3 cents per kilowatt-hours has also been discussed, and is becoming more and more of a reality. The model developed by Apostoleris et al. includes a baseline debt fraction of 60%, an interest rate of 5% and a return on equity of 10%. Thus, the total weighted average cost of capital falls to around "7%." In four independent projects, the PPA price falls at 5.84, 2.99, 2.94, and 2.35 cents per kilowatt-hours respectively. With the possibility of the unit price of energy being below three cents per kilowatt-hertz becoming more of a reality, the researchers encourage equatorial nations to implement utility solar plants as they continue to become more financially manageable.

The possibility of concentrating solar power in northwestern India has also been explored by Purohit et al. To meet the challenge of India's growing energy demands, this group contemplates the idea of implementing concentrating solar power within the rural landscapes of northwestern India. Following the analysis of India's current energy expenditure and questioning the viability of large solar constructs within the mountainous northwest, they conclude that the region has "favorable meteorological conditions for [centralized solar power] and large amounts of waste land" to place these plants (Purohit 17). They estimate that the maximum potential centralized solar power in India is over 2000 GW, which is a very large output of energy that could accommodate India's growing population.

Ortega et al. wrote a piece detailing the possibility of the mass implementation of solar infrastructure in Chile. The group discusses how Chile has made an active push to outsource coal usage domestically since the late 1900s. Scientists have labeled Chile since this period as the most ideal candidate to be completely driven by renewable energy with its abundance of waterways, sunlight, and windy conditions. However, a primary reason why these alternative methods of energy generation have not been as thoroughly implemented as prior thought would convey is that an atlas or documentation of alternative energy sources and their limits has not been made public by the Chilean government.

The group aims to provide a comprehensive assessment of the alternative energy capabilities of Chile by estimating quantities such as solar radiation per square mile to provide accessible and general information to Chilean citizens and world officials as well. They also make their case for the Chilean government to push for renewable energy sources by pointing out that the Chilean government does not produce its own fossil fuels and thus relies on importing coal from other nations at a high cost. In light of the Chilean government's recently declared interest in researching alternative energy methods, they conclude that it is now more possible than ever that Chile can implement solar technologies in particular if it garners the requisite amount of support through the passage of policy.

In the US, the concentrations of greenhouse gasses can be greatly reduced with the implementation of utility solar projects. Primarily, NO_2 emissions were greatly diminished as a result of the calculated solar power benefits in 2015. In total, avoiding emissions due to solar generation produced $1.3 to $4.9 billion dollars in air quality and public health benefits and $0.4 to $8.3 billion dollars in climate benefits. However, marginal emissions benefits for CO_2 were recorded across the country as a result of solar plant implementation in 2015. This is largely attributed to the emissions accrued through the construction of the solar plants, which is to be monitored going forward as suggested by Millstein et al.

Sivaram et al. argue that existing solar technology will not remain competitive due to its value decreasing as its penetration into the energy infrastructure grows larger and larger; they claim that a lower cost target of $0.25 per watt must be met to encourage the industry to either develop newer technologies that can beat this ambitious figure or to buy in on solar. They describe how industry executives are not in touch with ongoing research in solar photovoltaics and are fixated on solar panels being made of commonly available solar materials - like silicon and inorganic thin films - instead of newer manufacturing advances that will certainly allow for solar to be "competitive with fossil fuels" (Sivaram 1). They describe how the US Department of

Energy's target of $1 per watt for large-scale solar (around $0.06 per kW-hour) for unsubsidized solar to compete with natural gas, coal, wind, etc. is now within reach with the recent development of thin panels in research laboratories.

Some solar technologies have already been implemented in plants with these thin panels with a predicted "fully installed cost… below $1.00 per W by 2017." They discuss that solar prices at the moment are resistant from wholesale market prices because they have long-term fixed price power purchase agreements that are essentially 'locked-in' for a lengthy period of time. However, if solar reaches "20-30% penetration," as predicted by some models, utilities are more likely to set solar prices with wholesale market pricing. In other words, solar is predicted to lose value at about 30% penetration, and thus will be most efficient and financially stable when it comprises of 30% of the total energy expenditure of the United States.

These researchers suggest that solar output could be corrected to match demand by building energy storage which has experienced a gradual decline in price recently. However, the issue of energy storage price inflation also grows concerning as solar penetration increases to compensate for the variability in solar energy output due to seasonal changes in sunlight. Another way is for power purchasers to shift their own demand in response to market signals from the grid overseer to match the excess in solar output. This can be in the form of 'smart thermostats' or similar technologies that improve system efficiency. However, even this case will not be enough to mitigate the effects on solar deflation.

The idea of storing solar energy in domestic units has also been proposed as an alternative to having large-scale solar plants integrated within the grid. Fares et al. performed a cost breakdown of two scenarios: one in which households are given the ability to store solar energy using lithium ion battery storage to minimize the reliance on the utility against the full dependence of a household on the utility. Using 99 Texas households as a model, they predict “power demand, energy consumption, electricity service costs, and emissions of CO_2, SO_2 and NO_2 from the electricity system” (Fares 1). The group concludes that domestic energy storage would increase net energy consumption due to inefficiencies in insulation as a result of solar energy being stored within a domestic area rather than a plant. A grid driven on solar energy would be the most energetically efficient, though storage in domestic lithium ion batteries would ease the burden on utility providers that harness mass amounts of solar energy. As such, they compromise on a combinatorial solution to the problem: domestic solar panels and a utility powered by solar.

One question that comes up regarding the mass implantation of solar power is how much will society have to adapt to accommodate for the proposed 20-30% penetration of solar power into the current energy consumption model of the United States. While solar power has traditionally been perceived as the most natural alternative energy source as well as the most ‘futuristic,’ it will likely bring more misfortune upon already disenfranchised demographics under the current energy paradigm. Dustin Mulvaney discusses how decarbonization by solar-driven means should be carefully (1). He argues that, while we should strive to develop alternative means through which we can generate safe, clean energy for all, the ‘all’ should not be neglected if we choose to implement large-scale solar plants in the near future.

To pursue these efforts in the near future, Stoms et al. suggest sites of low conservation value with already limited biodiversity, such as the expanding Californian deserts that have been affected drastically by droughts in recent years. Targeting these areas would allow for governments to “avoid unnecessary conflicts and delays in the review and permitting process” that would dominate biologically diverse or even urbanized environments to be designated for reconstruction (Stoms 2). In these flat, non-urban areas, the Californian state solar target of 8.7 GW of installed capacity can be met by 2040.

The group identified specific target areas through a model they developed based on the “relative likelihood that a site will not incur substantial impacts” on the natural forces occupying these grounds. The group asserts their standard for the ‘compliance’ of a region subsumes the idea that no biological resources should be lost in the process of implementation. The factors that go into their measure of the *compliance* of a region are generalized between on-site degradation and off-site impacts. They describe on-site degradation as the extent to which landforms, either natural or manmade, will have to be destroyed to allow for the construction of large-scale solar arrays which logically must be built on a flat, even surface. Off-site impacts include the proximity of a region to other candidate regions that can be affected by the construction of large-scale solar arrays. Any natural resources in the neighboring areas of a candidate region could theoretically be harmed in the construction of these solar arrays.

They also describe the identification of about 5% of the entire studied area with high on-site degradation scores that are also distanced from regions that can be characterized as biologically diverse. The percentage of areas that complied with the off-site impact requirement was about 9%; however, the correlation between these two figures was only about 0.36; in other words, these regions are not exactly abundant in California. As they continued on in their discussion, they mention how the US National Environmental Policy Act highlights the four levels of taking care of environmental impacts - “avoid, minimize, restore, offset” (9). Generally, the price associated with each step goes up as one entertains each possibility from left to right. To further validate their argument, the group expounds on the idea that the candidate regions they have chosen are already degraded and whose reconstruction would thus incur minimum expenditures on state governments. The less money involved, the more inclined a state government would be willing to partake in a potentially cheaper and more eco-friendly alternative. They conclude that their model provides the clearest way to the immediate implementation of solar projects in desolate areas in the near future.

Further research has been dedicated to thermoelectric sources of energy which are a derivative of traditional solar power. Much argumentation has gone into the usage of solar as an individual source of energy against the idea that solar could be combined with another alternative form of energy production which could combine the benefits of both and reduce the drawbacks of widespread solar implementation. Novel thermoelectric developments have been created that are distinct from the traditional photovoltaic cells powering the most common solar panels in the world today.

These thermoelectric cells are designed to receive sunlight whose radiation can power a form of photovoltaic cell within the device while a portion is converted into thermal energy which can also be harnessed. In traditional solar panels, it is an unfortunate truth that not all radiation is converted into pure energy due to various complications in the transduction of the light (Karni). As such, having two distinct systems present like in the thermoelectric system allows for the minimization of lost energy since heat effectively becomes trapped within the copper plating surrounding the system.

The one issue plaguing the thermoelectric systems, in particular, is the cost and the relative efficiency to the most modern solar panels on the market. The cost should be adjusted as thermoelectric systems spend more time maturing on the open market in a fashion similar to solar panels when they first emerged. The inefficiency of the thermoelectric systems can be attributed to small errors in the design of the most recent systems, which are simultaneously the first of their kind. As more research goes into the development of more efficient thermoelectric systems, it is most likely that they will surpass traditional solar transduction mechanisms once it demonstrates the "potential for significant cost reduction… [and] the increase of efficiency" (2).

In summary, recent innovations and policies regarding the usage and implementation of large-scale solar units across the world have been met by public uncertainty and scholarly support. Despite the urging of scientists and economists to push forward with either solar or combinatorial approaches involving solar-driven grids, policy has largely failed to implement large-scale solar units within the grid as a utility. For these reasons, it will be increasingly difficult for the most modern photovoltaic technologies to become properly utilized when they can reduce the burden on utilities by a significant margin.

The mass incorporation of solar arrays in various nations has also been discussed and has been concluded to be a completely viable option in the sunniest regions of the world. These include, but are not limited to, India, Chile, the UAE and the southern United States. With the amount of flatland available in these regions, the ability for these nations to integrate solar machinery within their energy infrastructures is only limited by policy. Should other nations follow the UAE in offering willing financing corporations support, more large-scale projects can be initiated that will further diversify the way we consume energy.

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