Part I:  
An Introduction to Conventional Energy, Renewable Energy, and Rooftop Solar

Energy is the world’s most vital commodity. As a world commodity, energy has become globalized and the market under which it functions is a global market.¹ Energy is required for everything from transportation to the mass production of market goods. Not only is energy a commodity in and of itself, subject to fluctuations in market prices and supply and demand factors, it also is used to fuel the factories and warehouses that provide us with our products that in turn fuel the United States’ capitalist market. As so much depends on energy, it has become the world’s largest business and the most important commodity of our time.

Conventional Energy Sources

One of the biggest challenges that awaits us it how to expand our growing energy needs while protecting our planet for future generations. We are overly reliant on energy sources that are finite, rapidly dwindling, and contribute to a variety of issues such as environmental degradation, pollution, global warming, and associated health issues such as cancer and asthma, to name a few.² ³ However, it seems that no one source of energy provides an overarching solution to our energy needs. Fossil fuels, which consists of coal, oil, and natural gas, accounts for 85 percent of the energy used in the United States.⁴

These fossil fuels are efficient in the sense that they pack a lot of energy into a relatively inexpensive package but the carbon emissions from these sources are causing our climate to change rapidly and the markets that fuel the extraction of these resources is unstable.\textsuperscript{5} Hydropower offers us an emission-free alternative to the fossil fuel model and relied on power generated from water, which is a renewable resource. However, dams will often flood the surrounding lands and can have lasting effects on the health of the river ecosystems that they alter.\textsuperscript{6} Nuclear power plants can provide a tremendous amount of energy at a low cost, they are efficient, and emit no pollutants; however, we have still not found out a way to safely dispose of the nuclear waste, which makes this, too, an unrealistic alternative.\textsuperscript{7} Each of these conventional sources of energy has its positives and its negatives. The issue, it seems, is that the negative attributes of these sources are beginning to make the positives irrelevant.

Our nation’s power grid is in need of serious investment to support our ever-growing population and increasing energy demand.\textsuperscript{8} We continue to rely heavily on foreign oil from unstable regimes, and our idea of sourcing oil locally can cause devastating effects on native populations.\textsuperscript{9} We have a tremendously hard time developing

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\textsuperscript{5} Randolph and Masters, Energy, 23.  \\
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policies to combat climate change, let alone implement them.\textsuperscript{10} Energy is a necessity that is not getting any less important. The sooner we react and create more sustainable alternatives, the better.

\textit{Renewable Energy Sources}

It is misleading to think of renewable energy as a recent sustainable alternative to our impending energy crisis, as many forms of renewable energy have been around for longer than the conventional ones. Humans have been utilizing energy and power from the wind and sun for millennia.\textsuperscript{11} There are also many reasons why the movement away from fossil fuels is, and continues to be, so difficult besides simple inertia. The main two seem to be market driven. First, cost is a huge barrier for implementing widespread renewable energy, as many forms are accompanied by a tremendously high cost premium that makes their fossil fuel alternatives more economically attractive.\textsuperscript{12} The other reason has to do with the business world, as many fossil fuel companies are interwoven into countless sectors of the market, which makes it appear to be a daunting task to divest from them.\textsuperscript{13} Regardless of the setbacks, researchers, scientists, and economists alike are recognizing the great potential for renewable energy as an emerging market, as well as a saving grace for the negatives of our fossil fuel reliance.

\textsuperscript{12} Ehrlich, \textit{Renewable Energy}, 15.
There are five overarching categories of renewable energy that have spiked the interest of these economists and scientists as we look towards the future of a changing climate. The most proliferate form of renewable energy, or likewise the form we are perhaps the most accustomed to, is hydro, which is also a form of conventional energy.\textsuperscript{14} Hydro can come in the form of \textit{hydropower}, which is the use of a dam to block a river system and harness the power of falling water to spin turbines, or \textit{tidal or wave power}, which is the utilization of the oceans currents to spin turbines.\textsuperscript{15} As I will discuss later, hydropower, or dam systems, can have a devastating effect on the river systems that they block, causing lasting ecosystem damage.\textsuperscript{16} However, they are still considered by many to be an alternative energy source, as the energy produced by them is nonpolluting and renewable. Wave power has the potential to have less of an environmental impact but the turbine technology that we have currently is inadequate to support a large demand and it is enormously expensive.\textsuperscript{17, 18}

Turbine power is utilized elsewhere in the renewable energy sector with \textit{wind energy}. Wind is actually a form of solar energy—about two percent of the sun’s radiation that reaches the Earth is converted to wind energy via the heating and cooling of the surface of the Earth.\textsuperscript{19} When a portion of the surface area of the Earth heats up, the warm air will rise and allow cold air to take its place, thus creating wind. However, wind is

\begin{itemize}
\item \textsuperscript{14} Ehrlich, \textit{Renewable Energy}, 219.
\item \textsuperscript{16} Ehrlich, \textit{Renewable Energy}, 245.
\item \textsuperscript{17} “Tidal Power,” last modified February, 2017, http://www.energybc.ca/tidal.html.
\item \textsuperscript{18} “Why Hasn’t Tidal Power Taken Off?,” last modified May 20, 2015, https://www.technologyreview.com/s/537656/why-hasnt-tidal-power-taken-off/.
\item \textsuperscript{19} “Generalities about Wind Energy,” www.thewindpower.net/topic-51-generalities-about-wind-energy-1.php.
\end{itemize}
variable and unpredictable, which has prevented the wind industry from taking off in the United States.\(^\text{20}\) Also, the turbines are massive and require a lot of space, making it unrealistic for lower- to middle-class Americans to install one in their backyard, which relies on the assumption that many Americans are homeowners and thus have a private property space to install one of these systems.\(^\text{21}\)

The equipment-installation barrier can explain the pitfalls of biofuel as well. Biofuel, or biomass energy, refers to the use of organic material for energy generation.\(^\text{22}\) This organic material, typically in the form of plant debris or solid waste, essentially represents a reservoir of trapped solar energy.\(^\text{23}\) We as humans are an example of turning biomass into fuel, as we consume other animals that have consumed plants, which have converted the sun’s energy into simple sugars. As I am sure we have all heard before in an introductory chemistry classroom—energy is not created or destroyed but rather transformed. Considering that the Environmental Protection Agency estimates that the United States generates 200 million tons of solid waste each year, 67 percent of which is biodegradable, we have a tremendous potential to transform our waste into energy.\(^\text{24}\) However, the technology has not caught on entirely due to it being expensive as well as unsanitary.\(^\text{25}\) Take for example methane, the noxious gas that is released from rotting trash or manure. In order to be used to generate electricity, methane must be purified to


\(^{21}\) “A beginner’s guide to fossil fuel divestment.”


\(^{23}\) Ehrlich, Renewable Energy, 135.


eliminate the bacteria.\textsuperscript{26} There are sophisticated technologies that can do this, such as an \textit{aerobic digester}, which are tremendous if you have the money to purchase one and have the space to put it; otherwise, it is simply not economically feasible to have an aerobic digester on site.\textsuperscript{27}

Another form of heat energy is \textit{geothermal}, which is the utilization of the Earth’s heat to warm a building.\textsuperscript{28} For use within a building, this requires a series of heat pumps and pipes that are drilled down far below the surface of the Earth to tap into the heat. That is, as I am sure you have come to expect, extremely expensive to do.\textsuperscript{29} However, it is not impossible – the Weyerhaeuser Center for Health Sciences on the Puget Sound campus is actually heated via series of pipes underneath the building that span a total of six miles.\textsuperscript{30} The technology, however, is only regularly utilized for heating rather than electrical generation.

One last example of renewable energy is solar, which can be in the form of thermal or photovoltaic. \textit{Solar thermal} utilizes the sun’s energy to heat water to be used directly, or to heat another liquid that in turn will heat water via a heat exchanger.\textsuperscript{31} Solar thermal, also known as \textit{concentrated solar power}, has been used sparingly thus far for residential energy production, simply because it is designed for large-scale energy

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  \item[\textsuperscript{26}] Janardhan and Fesmire, \textit{Energy Explained: Vol. 2}, 47.
  \item[\textsuperscript{28}] Janardhan and Fesmire, \textit{Energy Explained: Vol. 2}, 49.
  \item[\textsuperscript{30}] “Where Our Energy Comes From,” last modified June 2016, https://www.pugetsound.edu/about/offices-services/facilities-services/sustainability-services/energy/where-our-energy-comes-from/.
\end{itemize}
Photovoltaic technology, on the other hand, is the most common form of renewable energy used by homeowners. Unlike some other forms of energy, a photovoltaic system allows residents and businesses to generate their power on site. As we have seen, conventional energy generation will often require fuel from locations that are far away from the place of residence for the customer, or require equipment that cannot be used on site. Other forms of renewable energy, such as wind and biofuel, have the potential to be used on site but usually require a large amount of space. Solar, on the other hand, maximizes the unused space of a building by utilizing the rooftop. From here on out, anytime I use the term “solar” to refer to something, I will be referring to solar photovoltaic technology, as opposed to solar thermal power or concentrated solar power.

Is Solar the Solution?

I do not mean to suggest that solar is the catchall solution for the world’s energy crisis. I do not think there is one catchall solution, which is a point that I will circle back to as we conclude this paper. The one thing that unites all forms of renewable energy is that they can be variable. Some say that the greatest paradox to renewable energy is that it has the potential to provide us with enough energy to support the planet but we do not have control over its production. Many forms of renewable resources rely on supplies that fluctuate in their availability and production. Additionally, they are not yet cost-competitive to the conventional forms of energy that dominate our lives. By promoting solar, I mean to suggest rather that solar is the most popular form of renewable energy for

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the masses due to its competitive pricing and ease of installation.\textsuperscript{35} Cost and access, however, are still barriers for many to enter the renewable energy market, even for a friendly renewable energy such as solar.\textsuperscript{36,37} My thesis investigates how this one type of renewable energy can be pushed even further and made to be affordable and accessible for everyone.

\textit{Rooftop Solar Systems: The Basics}

Rooftop solar systems are gaining popularity and the widespread acceptance of their effectiveness is becoming a reality. Rooftop solar, unlike other forms of renewable energy, allows homeowners and business to generate power on site. It is imperative that one who is investigating the feasibility of installing a photovoltaic system on their rooftop understands the basics of what constitutes a system. Without that basic knowledge, the customer cannot critically ask questions of the solar panel companies regarding the technologic specifics of how the system functions. One does not need to be a certified energy manager or a budding physicist in order to understand how the transfer of energy from sunlight to alternative current power occurs, as well as the equipment that is necessary to complete that conversion.

A basic photovoltaic system begins with the panels, also known as modules, which are located on the rooftop of a residential house, a commercial building, or some other structure that will allow for proper mounting and solar exposure. Solar panels are

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\item \textsuperscript{35} “Solar Energy,” http://extension.psu.edu/natural-resources/energy/solar-energy.
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often oriented so that they face south in order to capture the greatest amount of sunlight throughout the day. Even better are panels equipped with a device that will pivot to follow the arc of the sun throughout the sky; or, of course, if you have portable solar panels, a motivated human being who wishes to maximize the sun’s productivity could act as the pivoting device.\(^{38}\) Solar energy arrives on Earth in the form of solar radiation, which can then be converted into other forms of energy. We rely mainly on heat and electricity. The conversion of solar radiation to a form of electricity that we can use in our homes relies on the photovoltaic effect.\(^{39}\) The photovoltaic effect is the creation of a voltage or electrical current in a material upon its exposure to light.\(^{40}\) Sunlight is composed of photons, which for our simplistic understanding can be likened to individual packages of energy. When a photon strikes any surface, its energy may be reflected, absorbed, or allowed to pass through depending upon what the material is made of and its conductivity. Solar cells contain a material that allows the photon to be absorbed.\(^{41}\) This material is known as a semiconductor, which is silicon in solar panels. The semiconductor allows the energy from the photon to be transferred to an electron, which becomes part of an electrical current within a circuit.\(^{42}\) The resulting flow of electrons is called direct current electricity, or DC power.\(^{43}\) The amount of DC power that is generated by the solar panel is dependent upon how much input there was in the form of


\(^{43}\) Tester et al. *Sustainable Energy*, 572.
photons. Thus, the output is variable and dependent upon local weather conditions. Given optimal conditions, most commercially available solar panels operate at about ten percent efficiency, which is admittedly not great. The challenge is to make more efficient panels at a competitive price.

Once the conversion from photons to direct current electricity occurs, the DC electricity needs to be converted into alternating current electricity. This conversion is done by the inverter, which by itself does not create any power but rather converts the DC form into AC. From here, the electricity can be used by anything in a house or building that requires electricity. Typically, the electricity generated is run through a main panel in the house, which allows any piece of the equipment to source its power from there. There are other options, such as running the wiring to a panel that serves only a section of building, say one room, or to one type of equipment, such as the lights. This is particularly useful for marketing purposes to say things like “This conference room is run by 100% solar power” or “All of the lights in our home are run off of the electricity generated by our solar panels”. However, depending on the usage within a building or a home, one may not use all of the electricity generated by the solar panels. This commonly occurs with residential solar arrays where there is no storage system and the residents are gone during the day, which just so happens to be the peak time of production for the solar panels. A solution would be to install a battery system that would store the electricity generated by the solar panels until it is needed. However, battery

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systems are not widely used and their technology is not at the capacity of current solar systems.⁴⁹ Oftentimes they are inefficient, extremely expensive, and do not last very long.⁵⁰ Also, they are often made with toxic chemicals; thus, the creation of a hazardous waste that is potentially toxic to the environment is a big enough deterrent not to opt for a battery-operated storage system.⁵¹ A better solution has arisen, thanks to the utility companies that noticed an opportunity to purchase some cheap, locally made power. Commercial and residential solar owners can opt for a net metering system to be part of their solar array.⁵² Net metering allows system owners to receive credit for the excess electricity produced by the system. This means that if there is nothing in the house or building that is drawing energy, the electricity generated by the system will be transferred to the grid. These systems that produce more electricity than is used are credited for the excess production at their city’s retail electricity rate on their next month’s utility bill. That way, nothing goes to waste.

**Modifications on Solar Systems**

There are many modifications and customizations that can be made to the basic structure and components of a photovoltaic system. For example, there are various types of panels that have different efficiency ratings, as well as multiple types of inverters. The most common form of an inverter is a *string or central inverter*.⁵³ With this type, there is

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only one inverter for the entire system. This means that all the DC power that is created by all of the panels is run through one inverter. Because of this, the inverter’s maximum efficiency is based off of the lowest functioning panel.\(^5^4\) Just like all mass-produced pieces of equipment and machinery, such as cars, cell phones, and computers, each one functions slightly differently and one may be more efficient than another. If even one of the panels in the array becomes shaded, the amount of electricity generated by the system and converted by the inverter decreases to the productivity of the lowest functioning panel. Solar panels manufacturers recognized this drawback and a newer form of technology has come out, known as *mircoinverters.*\(^5^5\) Microinverters solve the issue of the inverter functioning off the panel with the lowest efficiency by allowing each panel to have its own mini-inverter to function based off of that panel’s efficiency. That way, the efficiency of the system is maximized. Now, this does not solve everything, as now instead of your inverter living safely within the walls of your electrical room, it now lives on the roof where it is exposed to the elements. Also, because they are a more recent form of technology and each panel requires its own inverter, opting for microinverters will dramatically increase the price of your array.\(^5^6\) However, some consider the optimization benefits to outweigh the negatives, making mircoinverters a better investment long-term. Even if one panel is shaded, the overall efficiency of the system will not decrease very much. Microinverters also allow you to monitor the power

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production of each individual panel to ensure preventative maintenance – if a panel is
down or functioning poorly, you can monitor it and known when to maintain it.

That may be more than you ever wanted to know about solar panels and, as I have
said before, one does not need to be an expert in order to install a solar array. One does,
however, need to be sufficiently knowledgeable in solar panel technology to ask critical
and pointed questions to solar panel salesmen. If you are able to articulate questions
regarding the inverters, the materials that make up the panels, and proper storage
techniques, the solar panel salesmen may be more likely to work with you on creating a
system that is best suited for your building, and for a fair price. Solar panel salesmen
have the potential to take advantage of customer’s mediocre understanding of a solar
system, as it is a relatively new technology. This is information that I found to be
beneficial when working to implement Puget Sound’s first solar array, which will be
discussed in a later section.
Part II:
The Solar Industry Nationally & in Washington State

The Solar Industry: Nationally

For those who are just starting to learn about the renewable energy sector, there are many resources available. One will find more resources available on the Internet than they will in textbooks, due to the rapidly shifting market and developing technologies that make it difficult to publish relevant text. One resource that is useful for both beginners within the renewable energy sector, as well as for experts in the field, is the National Renewable Energy Laboratory.\footnote{http://www.nrel.gov.} NREL acts as a collaborative effort between the federal government, the solar industry, and the public to compile a database of available information on photovoltaic technology. They also conduct case studies and efficiency experiments that assist with providing pertinent information for customer purchasing and market considerations. One of their projects, known as the Open PV project, seeks to rank which states are best suited for solar.\footnote{“The Open PV Project,” https://openpv.nrel.gov.} This ranking system is based on how much photovoltaic exposure the state has, how robust their legislature is for promoting solar projects, and the state’s current solar capacity based on how many solar systems are installed. The top rated state in the nation for solar installation, relevant legislature, and kilowatt potential is, as one might suspect, California. It is location in the southwest
region of the United States, which allows for an average of 6.5 kWh to strike each square meter of the surface of the state each day.\(^5^9\) It also has many bills in place that have some association with renewable energy, whether it is an incentive-based bill or a requirement for a minimum amount of renewable energy to be part of its grid system.\(^6^0\) It is ranked number one with 627,000 systems installed with a combined capacity of 7,400 megawatts of energy. Now, you may be wondering where Washington falls on this list. Contrary to what one might assume about the rainy state, Washington is not last on the list – but it is close. Washington is ranked number 38 for the amount of PV systems they have installed and its capacity for energy production. In Washington, there are 209 systems installed with a capacity of 2.09MW.

*The Solar Industry: Washington State*

Instead of solar, Washington has predominantly opted for another form of renewable energy – hydropower. Although hydropower is a nonpolluting form of electrical generation that burns no fossil fuels or extracts any resources, the devastating environmental effects it has on the river systems it blocks is gaining awareness. As an anecdotal side note, the best examples the powerful effects a dam, and what can happen when it is removed, is the Elwha River, located in nearby Port Angeles, Washington.\(^6^1\) For millennia, the Elwha River flowed free and powerful, originating in the Olympic National Forest and connecting to the Puget Sound through the Strait of Juan de Fuca.

\(^5^9\) “The Open PV Project.”


The river was the home to eleven different varieties of anadromous salmon and trout that would spawn in its waters and provide food for the Lower Elwha Klallam tribe who resided along its banks. In the 1800s, while the nation looked to the Norwest for lumber, the booming city of Port Angeles commissioned the damming of the river, which promised to fuel regional growth and provide power to the town. In doing so, the dams blocked the salmon from swimming upstream, disrupted the flow of sediment downstream, and flooded the historic homeland and cultural cites of the Lower Elwha Klallam Tribe. For over a century, the ecological and cultural connections to the river were broken. In 2014, the dams of the Elwha River were removed as part of Congress’s Elwha River Ecosystem and Fisheries Restoration Act. As a result, the salmon returned within a year and the ecosystem is slowly returning to its original function. The restoration of the Elwha River is being used as a global case study as to not only the ecological effects of hydropower dams, but also verification of how a biological system can respond beneficially when they are removed.

As the negative effects of hydropower come to light, many utility companies are beginning to experiment with other forms of renewable energy. Snohomish County PUD even has a permit to install a large water turbine in the Puget Sound, although there have been no concrete plans formulated. However, based on recent economic reports of Washington’s energy sector, the solar industry is experiencing the most growth and

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success.\textsuperscript{65} As we have learned from NREL’s Open PV Project, Washington is not ranked last on the list for solar exposure in the country, despite its rainy weather. In fact, Washington has many state-funded programs that encourage homeowners and businesses to go solar by subsidizing some of the costs. There are also federal incentives for solar, one of which is the \textit{Federal Income Tax Credit}, also known as the Solar Investment Tax Credit, which applies to all states.\textsuperscript{66} This is a credit for solar arrays that are installed on commercial and residential properties. Those who qualify receive a 30 percent tax credit at the time of purchase. In December of 2015, Congress acted to extend the 30 percent tax credit through the year 2019 with a step down in subsequent years: to 26 percent in 2020, to 22 percent in 2021, and thereafter it is zero for homeowners and 10 percent for commercial businesses.

Within Washington State, there are a couple of additional incentives that make installing solar more economically feasible. Washington offers a \textit{Sales Tax Exemption}, which ensures that systems that are at or less than 10kW will be exempt from having to pay sales tax on their array.\textsuperscript{67} Systems that are larger than 10kW will receive a 75 percent sales tax exemption. Considering that sales tax within Washington State is one of the highest in the nation—8.89 percent combined state and local rates, with a 10.1 percent in Seattle—the sales tax exemption makes a large difference, as an average 10kW system will run you about forty thousand dollars. This exemption, however, has a sunset date of 2018, after which all system owners will be required to pay full sales tax on their array.

\textsuperscript{66} “Solar Incentives,” \url{http://www.solarwa.org/solar_incentives}.
\textsuperscript{67} “Solar Incentives.”
Another Washington State incentive program is the Washington State Production Incentive. This program is where the bulk of the money can be returned to solar panel owners. This incentive is aimed to reward property-owners for installing made-in-Washington photovoltaic systems. This includes both the panels and the inverters. Currently, the only Washington State company that manufactures the panels is Itek Energy based out of Bellingham, Washington. There are about a dozen other companies that manufacture the inverters, as well as other pieces of equipment that are necessary for rooftop solar. If a system has both made-in-Washington panels and inverters, the owner will receive $0.54 per kWh produced for homes and commercial businesses. The Washington Legislature has even extended this for systems that do not have locally made equipment, to which they will receive $0.15 per kWh produced. There is a restriction on how much each utility company can contribute to the program, which is capped at 0.5 percent of their taxable sales for the year. This incentive also has a maximum payment cap of five thousand dollars annually, which is still a considerable amount of money considering the average electricity rates in Washington are far less than what the incentive program pays. The average electricity rate for residential customers is $0.12 per kWh and $0.07 for commercial customers; however, depending on your utility company and rate structure, the price for conventional electricity could be even lower. Along with the other incentive programs, the Washington State Production Incentive will be gone by 2020 and no payments will be made on any kWh produced after that date. If you are feeling like the solar industry is going to drop off at the end of say, 2021, and no

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68 “Solar Incentives.”
incentives will be left, you are not alone. The solar industry and the Legislature recognize this and are struggling to address the issue, which has been a critique by many of the inadequacies of the solar industry.
Part III:  
The University of Puget Sound Solar Pilot Project\textsuperscript{71}

My Background

Despite a solid understanding of energy systems and renewable energy now, I started out this project knowing an embarrassingly small amount of information about electrical generation and energy systems. My interest started in the beginning of my first year at Puget Sound, where I began to work for a subset of Facilities Services known as Sustainability Services, which is a small, student-run program that oversees recycling and waste-reduction efforts on the Puget Sound campus. I worked as the manager for the program for three years, where I supervised a team of fifteen work-study students, helped to oversee the recycling program on campus, and participated in public awareness campaigns on waste reduction. In the summer of 2015, in between my sophomore and junior year, I was the recipient of the Sustainability Advisory Committee’s Summer Research Grant. The Sustainability Advisory Committee is a collaboration between students, faculty, and staff on campus to ensure that we as a campus are incorporating sustainability into all departments and offices, from the Collins Memorial Library to

\textsuperscript{71} See bibliography.
Dining and Conference Services. My directive for the grant was to investigate what solar technologies were available in today’s market, what companies provided solar installation in the area, and the best way to go about getting solar on the Puget Sound campus. At the end of the summer, I put together a report of my findings. Following the project, I began a new position within Facilities Services as the Resource Conservation Manager, where I continue to work on the solar project and could focus on energy efficiency and conservation here at Puget Sound.

*Considerations for University Solar Projects*

Getting solar on the roof of a residential home can sometimes be a daunting task and implementing a university-scale rooftop solar system has its own set of challenges. However, the processes and considerations that need to be made to ensure that the system is appropriate for the building are largely the same. Throughout the project, I worked with my supervisor, the Sustainability and Energy Manager, as well as with the electrical and engineering team of Facilities Services. From my experience, I have come to understand what must be considered when a university, or a homeowner, is looking to incorporate solar into their energy portfolio.

There are many different considerations that a university, or the owner of a building, needs to make concerning a rooftop solar system. All of the considerations are easier to make if one has a general understanding of the components of a solar system and how it connects to the grid, as I discussed earlier. Having some working knowledge of the system, and perhaps even an idea of what you want, will help to make the interaction more authentic and productive. It can go without saying that one of the first
considerations you will want to make is what company you are going to work with. This may become a more obvious choice once you get an idea of how much a solar system will cost and how competitive the pricing is between companies. It is helpful to get multiple quotes for a solar system from different companies. For my project, I ended up acquiring quotes from three different companies, after which it was easy to identify a company that would be the best to work with based on pricing and customer service.

Another consideration that will need to be made is the size of the system. This question can be answered with greater ease if you have an idea of what the project is going to be for. A solar project could be used to offset a certain amount of power, from which you will have a good idea of how large to build the system, or it could be for another purpose. One such purpose could be for demonstration, meaning that the solar array could be used as an educational tool for what solar technology is and how it is utilized. This may cause the size of the system to be on the smaller end, as education projects are often in line with pilot projects where the university or company may be wanting to simply test the waters, so to speak, of the solar industry, with the intention of installing a larger system in the future. The size of the system may also be determined based on pricing. Larger systems are inherently going to be more expensive but sometimes purchasing a larger system will decrease your payback period, as they can inherently produce more energy. Also, the fact that systems that are less than 10kW are exempt from sales tax is something to consider as well. It is also useful to assess what effect the incentives will have on the payback period for the array. Remember that the Washington State Production Incentive, which allows system owners to receive $0.54 per kWh generated, is contingent on the fact that the system was built with made-in-
Washington equipment. This may encourage some to opt for locally made equipment but, as has been my experience, it is generally more expensive than out-of-state, or even out-of-country, equipment. The out-of-state equipment therefore has a cheaper upfront cost but the customer will receive less money in the form of incentive payments, thus a longer payback period. Besides the cost difference between in-state and out-of-state equipment, there is also a difference in cost between string or central and microinverters. As microinverters are a newer technology, they come at a higher cost. However, as discussed earlier, they are more efficient and have the potential to prevent lost energy from their inefficient counterparts.

Once you identify what kind of equipment you want in your system, the size, as well as the company you will be working with, there a couple additional considerations that need to be made, such as who is going to be responsible for monitoring and maintaining the panels. Some companies have that as part of the contract, stating that they will provide routine maintenance for the panels. Solar panels and inverters typically last 20 to 25 years but, depending on routine maintenance, have the potential to last longer. Additionally, microinverter technology will allow remote monitoring of the system down to the panel level, so both the customer and the installation company will be aware if a panel goes offline. Typically, once solar panel systems are installed, they require little maintenance or cleaning and the good news here in the Pacific Northwest is that the rain does that job for us. A final consideration that will need to be made is how you are going to track the electricity produced by the system, or if you want to at all. The solar panel installation company will install a meter that will allow them to track the production of the system, as to ensure that you receive the proper incentives associated
with the energy production. You can add an additional package to your system that will allow for you to have access to an online dashboard that allows for tracking and some analysis of the data but unless you plan on conducting some data analytics, that information may be irrelevant. Net metering systems are also another consideration to make, if you are expecting to produce more electricity than you will use. These are all considerations that myself and the other people working on the solar project needed to make as well, with a couple additional university-specific considerations.

*Puget Sound’s Pilot Project*

Although we received quotes from three different companies, each of which were located in the greater Seattle area, the company we ended up deciding to work with was Puget Sound Solar. We chose them over the others due to their prompt customer service and thorough site evaluation, as well as their competitive pricing that made the cost for installing the system more attractive. We ultimately decided upon a 9.9kW array, making a conscious decision to stay below the 10kW sales tax exemption cap. This was intentional, as we decided that we wanted to save the most amount of money upfront. Unlike other commercial properties, the University does not qualify for any of the incentives associated with the array as they are a not-for-profit and do not pay sales tax. It was, therefore, in our best interest to save the most money in the overall net cost of the system. Besides the sales tax exemption, we also sought out-of-country made equipment to cut down on the costs. We were quoted a ballpark value of $26,000 to $30,000 for the entire system, including installation costs. In the quote from Puget Sound Solar that we liked the best, a Canadian company made the panels and inverters. Besides this decision
to cut down on costs by avoiding high taxes and tariffs, there was also quite a bit of consideration that went into the location of the array.

Identifying the location to install the solar array was one of our biggest concerns, as many of the buildings on campus have heavily pitched roofs that have tiled or shingled roofing, both of which are less than ideal combinations with heavy, expensive glass panels. Also, solar exposure on campus is not all that great, as many roofs are shaded during the daytime due to the dense canopy present in some areas. It turned out that Facilities Services, located at the south end of campus, was the best place for the job.

During Puget Sound Solar’s site evaluation, they measured the solar exposure the south-facing roof to determine its kWh potential. This measurement was done by a solarameter. The roof of the administrative building of Facilities Services had a 96 percent solar exposure, meaning that of all of the sunlight during the course of a day, 96 percent of that will strike the roof. The final consideration we needed to iron out before the project was a go was an issue surrounding the backup generator. Facilities Services is an emergency response building, meaning that in the event that the rest of campus loses power, the backup generator located at Facilities Services would turn on to provide power to campus. There were some concerns that if the grid went down and the panels were still producing electricity, then the backup generator might mistakenly turn off, thinking that the grid was back up. This issue was mitigated by the fact that the solar system has in place a sensor that would recognize the grid being down and would shut off automatically. While each of these considerations seems tedious and detailed, each was an important step forward to getting the system installed and security funding for the project.
Completing the Project

From working on this project, I have learned that, despite the incentives in place, sometimes going solar is not the most economically feasible or it may not have the biggest environmental impact. It turns out that, for the University right now, solar is not the way to go. There are two main reasons for this, first that there was too much discussion surrounding the intentionality of the project. Now, one might assume that yes, of course a university such as Puget Sound would want to opt for solar panels, being that sustainability is one of their key mission statements. However, there was too much debate and not enough cohesion on the purpose of the project. Many questions persisted as to whether or not solar was something we wanted to invest in, as the system we were leaning towards did not offset that much power, had a long payback period, and was relatively expensive. While attempting to reconcile this, we decided that the goal of the project should be education, meaning that we would use the solar array as an education tool to demonstrate what photovoltaic technology is and how it is used. This realization came too late, I believe, and there was already discussion about using the money for something else. Ultimately, the money will be used to fund a lighting retrofit of the Tennis Annex in the Memorial Fieldhouse, where the outdated sodium-halide bulbs that light the courts now will be replaced with energy efficient LEDs. This project will be completed in the summer of 2017. The lighting project offers a better opportunity to
offset more energy and have a bigger effect on our environmental footprint. This realization that solar may not be the way to go is a common setback for solar projects. If we were to have identified our mission statement from the beginning, we could have been communicating why solar was the best solution to our problem from the beginning.

Unanswered Questions

While this is most likely the end of the solar project as long as I am a student here at Puget Sound, I was left with some big questions that I have worked to answer. The first of which is: Is there a better way to fund solar projects? Because Facilities Services was funding the project themselves, it was easy to pick up the money and use it for a better project when the opportunity arose. It was also a large sum of money to front at one time, but the University has a considerable endowment and there is money allocated in the budget to fund energy efficiency projects such as this. The University is privileged to be able to fund a project of this magnitude with this type of impact. I was curious about those who cannot afford to fund a solar array, or those who are not homeowners and do not have a place to install solar. I wondered what the affect of providing increased access to the renewable energy market had on a community, which lead me to my second question: What is the potential of renewable energy? Why solar? I was curious about how solar can be used to benefit a larger community, either through education or by other means. While grappling with those two questions, I came across an idea of a unique way to fund solar projects, known as Community Solar, that I believes provides us with an answer.
Community Solar is a Washington state program that acts as a collective or sharing model for going solar. In essence, a group of participants or an organization, such as a utility company, will sponsor the construction of a solar array, where customers can purchase shares, or panels, of the array and receive the incentives associated with the system that the utility company cannot receive. This model of Community Solar begins to provide answers to the questions I was left with after finishing the Puget Sound solar project. Community Solar opens the door to many other groups of people who would otherwise have been excluded from the market, by providing access to solar without the previously assumed requirements: a roof and a large budget. Now, anyone can be a part of the renewable energy sector and ultimately, and hopefully, have power in pushing the market towards favoring renewable energy over fossil fuels. Community Solar also provides an answer to my second question surrounding intentionality. Public awareness is inherently expanding by exposing more people to photovoltaic technology, as more people know about solar and see that it works and that the paybacks are substantial.

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How Community Solar Works

The way that Community Solar projects function is surprisingly simplistic. First, a utility company or an LLC will sponsor the building of a large array. The utility company that sponsors the solar array is responsible for maintaining it and making any repairs to the system throughout its lifetime. On paper, the utility company owns the array; however, they defer the upfront investment costs by offering their customers and associated community members to purchase shares of the array. These shares can be likened to panels, being that you may buy three one-hundred-dollar shares, which is roughly equivalent to one panel. The owners of the panels will then receive the incentives that are associated with the array. One of these incentives is a credit to the customers’ utility bill for the portion of the total solar energy produced by the system for each billing cycle, as per the electricity rate in their area. The utility company is essentially buying from the owner the electricity that is produced by their panels. Another incentive that the customers receive is a one-time 30 percent federal tax credit on the price of their share, which is the same incentive that customers of any type of solar system across the country receives. The third incentive that customers receive is also similar to one that regular solar customers qualify for but this incentive is far more robust and allows for

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73 Phone calls, June 2016-January 2017.
Community Solar customers to have a payback period that is far shorter than if they would have purchased the solar system themselves. Community Solar customers will receive annual payments from the Washington State Production Incentive double of what a homeowner or a business would receive – instead of the generous $0.54 per kWh for regular customers, Community Solar customers receive $1.08 per kWh.74

**Beneficiaries of Community Solar Projects**

The customers of the Community Solar programs are the clear victors in this business transaction, as they are getting paid roughly ten times that which the electricity produced by the panels is actually worth. This allows them to have a payback period of about four years from their initial investment. Compare that to the average payback period of ten years for regular solar customers.75 Besides the customers, the building on which the array is located also benefits, as they will receive the electricity produced by the system and their electricity bill will decrease as a result. In conjunction, the utility company who sponsored the array will also benefit, as the array functions as another power generation source and ultimately decreases the amount of electricity they need to produce conventionally to meet peak demand. Lastly, Washington State solar manufacturers benefit from the program, as the increased Washington State Production Inventive that Community Solar customers receive is contingent upon the fact that the system was made with Washington equipment. Overall, Community Solar projects

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increase the incentives that customers of solar would receive on their own, as well as expand the realm of potential customers beyond those that own their own home.

*Case Study: Tacoma Power Community Solar Project*

In order to find proof that the Community Solar program worked, I sought out a case study to use for my investigation. The system I chose as my case study was Tacoma Power’s Community Solar project located on the roof of their warehouse building on South 35th Street. I chose to use this project as my case study as it was local and was a functioning model from which I could gather information. This project is in a space that is a prime location for a solar array, as it is on an open roof space that was otherwise serving no function. The system built is a 300kW array with four different subunits, each 75kW, which maximizes the space on the L-shaped roof. The project was fully funded from customer buy-ins, which were sold at one-hundred dollars a share. All of the shares were sold out within a day. The expected payback period for customers is four years but depending on how many shares purchased, some customers have already been paid back in full. For all intents and purposes, the Tacoma Power Community Solar program functions the same as any other project, with one exception – Tacoma Power’s customers will receive the Washington State Production Incentive past its sunset date of 2020, which has been extended until 2036. Although there is no clear reason as to why Tacoma Power has extended the sunset date of the initiative program, one could suspect that it is a method of securing customers. As the majority of the customers of the Community Solar

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76 Tacoma Power Community Solar Site Visit, October 2016.
project were already Tacoma Power customers, and one must remain a citizen of Tacoma in order to receive the incentives associated with the project, one could assume that Tacoma Power extended the sunset date in order to ensure customers remain in the Tacoma area. Being that Tacoma Power is one of the only distributors of electricity in the area, Tacoma Power would be securing their existing customers for subsequent years. However, that is only a hypothesis as no explanation has been presented to suggest otherwise.

Tacoma Power’s Community Solar project is by no means the perfect model, rather a functioning model that was local and was very well received by the community. There are many other models and versions of community solar projects that may or may not be more successful. Just as there were many considerations that needed to be made for the Puget Sound solar project, there are many factors that go into making a Community Solar project successful. One element that appears to be lacking in the Tacoma Power Community Solar project was visibility and marketing. The system is on a roof that is relatively visible from the road but the building is not being used by any entity other than Tacoma Power. The system, in a way, directly helps Tacoma Power. I wanted to find another project where the solar panels benefitted more of the community other than the utility company and its customers.

*An Alternative: Seattle City Light Community Solar Project*

Seattle City Light offers a Community Solar project that adds greater visibility and allows for a larger portion of the community to benefit. Seattle City Light currently has five Community Solar projects, all of which are sold out. Their largest and most
popular one is placed on the roof of the Seattle Public Aquarium. This particular project functions the same way as the Tacoma Power project, it is just that the panels are in a more public space. Visitors to the Seattle Aquarium can go on a sustainability tour of the building where they can learn about the panels and how they are funded. The workers in the Seattle Aquarium are also tremendously proud of the solar array on their roof and express gratitude to the customers who participated and help fund the project, as the aquarium would not have been able to pay for the system on their own. To me, this exemplifies the true potential of renewable energy, which is to fuel a community and benefit more than an individuals but rather the collective as a whole. By placing the panels in an extremely public space, public awareness is being raised about solar technology and its relevance. Seattle City Light’s Community Solar project on the Seattle Public Aquarium offers us a unique adaptation to the Community Solar project model by adding more of a community aspect to the project.
Part V: 
Assessing the Effectiveness of the Community Solar Program

The Community Solar Bill: Funding & Goals

In order to understand the impact that the Community Solar program has had on the energy sector within Washington State, one must first have a working understanding of the legislation that put it in place. After that, one can begin to understand the successes, and potential shortcomings, of the program. The Community Solar program is supported and backed by a series of bills that have been put in place throughout the last twelve years. In 2013, Congress passed the Climate Action Plan that was put forth by President Obama.\textsuperscript{77} The Climate Action Plan aimed to cut carbon pollution in the United States, prepare the United States for the impacts of local climate change, and lead international efforts to address global climate change. The Climate Action Plan has given eight-billion dollars in loan money to seed investments in innovative technologies to reduce our reliance on fossil fuels, to which a goal was set to reduce carbon pollution by at least three billion metric tons cumulatively by 2030.\textsuperscript{78} As a response, Washington State

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created an Energy Independence Act, which requires large utility companies to obtain 15 percent of their electricity from *new* renewable resources, such as wind or solar, by 2020.\(^79\) This means that any renewable energy that was preexisting in the grid prior to 2013, when the Act was enacted into law, does not count towards the overall 15 percent. The bill that provides the money for Community Solar projects, known by the Washington Legislature in Olympia as the Renewable Energy Cost Recovery Incentive Payment Program, was an easy way for the utility companies to meet those demands without having to be responsible for the upfront investment costs. It was also a bill that was already in place – the Community Solar bill was passed way back in 2005 but did not gain traction, nor was it heavily utilized, until recently. The bill outlines the following goals as part of its original intention.\(^80\)

1. To use local renewable resources to generate electricity.
2. To reduce the load on Washington’s electrical grid.
3. To provide nonpolluting sources of electrical generation.
4. To create jobs by supporting local solar manufacturers.

During the time in which this bill was passed, the political climate in Washington State surrounding the bill was different than how it is now. Even back in 2005, the major cities around Washington’s Puget Sound were experiencing an increase in population growth.\(^81\) This caused concern that, if the population in the Puget Sound continued to grow, that the regions’ electrical grid could not support the capacity and demand of the influx of


people. It is the hope that renewable energy will act as a supplement to conventional energy sources and reduce the load on the electrical grid. Additionally, the solar industry in Washington was starting to take root. By providing some subsidies for customers to enter the market, it was the hope that the local solar manufacturers would experience an initial boom in production. Overall, the Community Solar bill’s intentions are broad and provide a multitude of benefits for multiple parties involved.

Assessing the Effectiveness: The Bill

In order to understand how widespread the benefits of the Community Solar program were, and continue to be, one must first assess the effectiveness of the program overall. There are two ways to assess this – first, to look at how well the programs aligned with the original intention of the bill and second, to assess the long term viability of the program. By looking at both the legislative, as well as the implementation, side of the Community Solar programs, it is my hope that a holistic understanding of how well these programs actually functioned will be generated.

Based on my research, the Community Solar bill was successful as it followed the original intentional of the bill. The program met the first goal by using local and renewable resources to generate electricity, as solar is a renewable resource and the equipment used to create the arrays was all Washington-made. The second goal was also met, as the program provided nonpolluting sources of electrical generation. The third goal, which was to help reduce the load on Washington’s electrical grid, is ambiguous as to whether or not it was met. There has been no study or assessment to determine how

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much electricity all of the Community Solar programs in Washington State have offset. Furthermore, we do not know how much electricity was making it back into the grid if one of the buildings was not using as much electricity as the array was producing.

Finally, there is no precise count for the number or solar systems that have been installed from the Community Solar program, as many have applied for the funding but have not started construction of the array. The only thing that we know with accuracy, and the only statistic the Legislature has been tracking since the onset of the program, is how much money has been paid out in the form of the Washington State Production Incentive. All we know is that an estimated 7 million dollars will have been provided to Community Solar customers by the sunset date of the production incentive by 2020.83

Our final goal, which aims to create jobs by supporting local solar manufacturers, is also unclear as to whether or not it was met. Theoretically, the Washington State solar manufacturers would have had an increase in revenue through the creation of those new solar panels and inverters to participating Community Solar programs but, again, we do not have a good estimate as to how many arrays were installed as part of the bill. It is my guess that the Legislature will conduct some sort of assessment at the end of 2020 to communicate to the public the successes of the program, but as of now that has not happened and it is not outlined in the bill that that be a requirement. Overall the goals set forth by the original Community Solar bill were met, or at least did not suggest anything otherwise. However, the fact the Community Solar program followed the intentions of the original bill does not give the full story of how well the program functioned and its effect on the community.

Assessing the Effectiveness: The Program

As we have seen, the Community Solar program has worked very well and has, for the most part, followed the goals set forth by the bill. I would argue, however, that the popularity of the program has exposed a weakness in the long-term viability of the Community Solar program. We have seen that the popularity of these projects is insurmountable – the Tacoma Power Community Solar project, as well as many other projects I investigated, sold out in an extremely short amount of time.\(^\text{84}\) This has forced many utility companies to put a cap on the amount of incentives that are paid out.\(^\text{85}\) Larger utility companies, such as Seattle City Light and Snohomish County PUD, have to notify Community Solar customers that their annual Washington State Production Incentive checks could be reduced because the program was oversubscribed to. As we know, there will be an estimated total of 7 million dollars in the form of production incentives that will have been paid out to customers by the end of the program. This is tremendous from the perspective of how much renewable energy was added to the grid, yet problematic in terms of creating a sustainable business model.

Besides the oversubscription issue, something else that stood out to me is the seemingly ambiguous 2020 sunset date. I could not find anything in the bill that identified the reasoning behind the precise cut off date. I initially assumed that it was the date at which the funding allocated to the project would theoretically run out. However, since many programs in larger cities were running out years before the projected cut-off

\(^{84}\) Tacoma Power Community Solar Site Visit, October 2016.
date, I knew there had to be another reason for the precise 2020 date. The answer lies in
the Energy Independence Act. Recall that one of the original intentions for the
Community Solar bill was to help create energy independence for Washington State.
Community Solar projects help kick start the development of solar arrays by having
customers provide the initial investment for the project, while continuing to receive
benefits from the program for subsequent years. By allowing customers to own their own
solar panels, the customers are theoretically more inclined to care about their panels and
the renewable energy sector as a whole. At least, that it what the Washington State
Legislature hopes for, stating that “[after 2020.] the state’s renewable energy industry
will be capable of sustained growth and vitality without the [need for] the cost recovery
incentive,” otherwise known as the Washington State Production Incentive.\(^6\) I have
found no evidence from any of my sources that the Washington State solar industry will
be self sufficient come 2020 and I am curious as to what information the Legislature
found to support this claim. It is true that the program has had tremendous success but the
incentives that are left are running out, and soon there will be no incentives left. In fact,
all monetary incentives for solar, not just for Community Solar, will be gone by the end
of 2021. Without the government subsidies, many fear that the solar industry will be left
to fail and all of the work done to build up the sector will be for naught.

Part VI:
The Future of Solar in Washington State

New Legislation: The Solar Bill

While no one can predict market fluctuations and changes, there are some pieces of evidence that point towards where the solar market could go in the future. One of those is the new law that is being pushed through the Washington State Legislature. House Bill 1048, or more affectionately known as the Solar Bill, was introduced when the Legislature in Olympia started their 2017 session. Shortly afterwards, there was a public hearing on the bill where it was moved to the House and, as of the beginning of March, the bill was moved to the finance department of the Washington Legislature for further deliberation. The Solar Bill was reintroduced as a modification on a previous bill that was proposed to the Olympia legislature and overturned in 2016.

The Solar Bill is set to grow the state’s solar jobs significantly while making the solar budget more cost-efficient. Recall that the current Washington State Production Incentive is $0.54 per kWh for residential- and commercially-owned solar arrays, and $1.08 per kWh for Community Solar customers. With the average cost of electricity

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87 “House Bill 1048.”
running about $0.12 per kWh for residential customers and $0.07 per kWh for commercial properties, the incentives that customers receive is way beyond what the electricity is worth. This is one of the main reasons why the Community Solar program has run out of funding so quickly, as it is relying on an unsustainable business model. In an attempt to remedy this, the new solar bill will “reduce” the Washington State Production Incentive from what it has been in the past. Unfortunately, nowhere on the new bill does it say by how much it will be reduced, which is supposedly what they are currently deliberating in the finance department of the Washington Legislature.

Additionally, the new bill seeks to increase the state’s revenues by eliminating the sales tax exemption early. Re-activating the sales tax paid on solar arrays will, as the Legislature puts it, allow the Community Solar program to pay for itself in the first biennium. The new bill also aims to expand utility participation by increasing the amount of taxable revenue available to pay out the incentives from 0.5 percent to 2 percent, which will hopefully allow smaller utility companies to sponsor Community Solar projects, as well as prevent them from exhausting their funding so quickly. Lastly, the new bill aims to ensure certainty for new solar owners by allowing customers to receive eight years of incentive payments at the rate at which they joined the program. Old solar customers will also have secure rates, as the new bill will maintain their existing rates until 2020. Now, we know that the old version of this bill did not pass, nor did it even make it through to the Legislature. One potential explanation for this was there were potentially competing sustainability-related bills that were trying to make their way through the Legislature. In 2016, Washington was attempting to pass Initiative 732, otherwise known as the Washington Carbon Emission Tax and Sales Tax Reduction,
which would have created our region’s first carbon tax.\textsuperscript{89} Media publication regarding the initiative dominated many news and media outlets as it gained popularity, potentially leaving the old version of the solar bill in the dust. As last year’s local election coincided with the national election, the popular carbon tax bill may have overshined the previous solar bill in popularity. While the carbon tax initiative failed, this may leave room for the new Solar Bill to take ground and pick up some support from old supporters of Initiative 732.

\textit{Are Subsidies Necessary?}

There is disagreement as to whether or not subsidies on renewable energy technologies are truly effective. This argument typically comes about when discussing policy, mainly the idea of the free market economy versus market intervention. Those on the side of the free market economy will generally argue that government subsides interfere with the action of supply and demand. They also cost the government a tremendous amount of money, which is often sourced from taxpayer dollars. There is some evidence to support this: from 1999 to 2007, the cost of energy in the United States rose 80 percent while usage increased by only 5 percent, despite the fact that the same amount of energy was produced in 1999 as it was in 2007.\textsuperscript{90} Those on the side of market intervention, however, see things differently. They will argue that tax credits are necessary to make renewable energy cost competitive to the conventional energy sources and that the government must assist these new technologies, or else they will not be able

to compete in the free market on their own. From my research, I understand that it is the subsidies and the incentive programs that are really what encourages people to invest in solar in the first place.

If the incentives that help customers start solar projects are eliminated entirely, it would be my educated guess that there would be less interest in Community Solar projects, as well as in solar in general. The Community Solar projects did not sell out in a matter of minutes because people love solar, it sold out in a matter of minutes because it had a good return on investment and promised payback to customers for many subsequent years. Without the incentives, the payback period would most likely be extended, which would probably cause people to think twice about investing in the industry. With that being said, the cost of solar panels goes down all the time, which may decrease the upfront cost of a solar system.91 Solar panels often experience fluctuations in market prices, mainly due to periodic silicon shortages and the variable prices of other energy sources, such as natural gas, which is currently at a record low.92,93 It is estimated by the National Renewable Energy Laboratory that the price of solar panels and inverters halves approximately every ten years.94 The lowering cost of the panels, along with the raising awareness of their effectiveness, may help the renewable energy sector seem more attractive to potential investors. Contrary to the Washington State Legislature, however, I

do not think that those two things alone will allow the industry to be self-sufficient by 2020. What I do know is that if the new Solar Bill does not pass, there will be no monetary incentives for individuals to invest in solar. Without these incentives, I doubt that the interest in solar will be as high as it is now. I believe that the best solution will arise with some cuts on the incentives program to ensure that the program does not exhaust itself of funding, while maintaining subsidies on investing in the industry. That way, more solar projects will be able to be built, the market will remain open to a wide range of people with different socio-economic statuses, and the industry will grow slowly over time.

**Why Is Community Solar Not More Widespread?**

Even though we may have a comprehensive understanding of the benefits, and potential drawbacks, of the Community Solar program, and even a good idea of what solar will look like here in Washington in the future, there are a few questions that remain unanswered and up for discussion. One such question is: *If these Community Solar projects were so successful, why are we not doing this everywhere?* One way to answer that question is to propose the opposite and claim that we are. The idea of community solar is gaining ground in other states. At least ten other states have adopted bills that fund programs that are, or act like, community solar programs.95 In many other states, these are known as *Community Solar Gardens*, shortened to CSGs, but function the same way as Community Solar projects but are typically in off-site locations.96 *Shared solar is

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a slightly different idea where instead of a utility company sponsoring the building of a solar array, a community group or a group of homeowners will build a large array and share the power that is generated.\textsuperscript{97} This can either be on-site, like on the roof of an apartment complex, or off-site. Shared solar is gaining popularity in close-knit communities that already have a communal aspect, such as within a gated community. Some states have even adopted Community Solar programs that have no sunset dates, so that the customers will receive electricity payments for the entire life of the panels.\textsuperscript{98} These are all valid options for different states, and depending on the political climate of the legislature within that state, one form of subsidized group solar may be more attractive than another.

Another way to answer the question regarding the lack of continuation of the Community Solar program is to blame it on poor marketing. For many of these Community Solar projects in Washington State, those that were able to buy in to the project had to be customers of the utility company who was sponsoring it. That excludes many who may live in an area where their utility company does not offer a Community Solar program. Additionally, as we have discussed before, the Legislature has done no survey, study, or investigation into the successes or failures of the program. Therefore, the public has no way of knowing if this program works, other than if they are already customers. This decreases the potential amount of public backing to support the proliferation and continuation of the program.

Issues of a Completely Renewable Grid

One cannot discuss solar technology and alternative energy without receiving the question: *What about a 100 percent renewable grid?* This question cannot be answered simply. There is the concern that renewable energy, as I discussed in the beginning of the paper, is inherently variable due to its reliance on weather events, such as tidal currents, winds, and sunlight. Due to this variability, we cannot rely on renewables as our only source of energy and must have supplemental energy from conventional sources. The argument to diversify our energy portfolio to not rely on one source, but rather on many, is a solid argument as it takes into consideration market fluctuations that will occur in the future. Fossil fuels are a finite resource, which often increase in price as their supply decreases.

Another issue surrounding a 100 percent renewable grid is peak demand. *Peak demand,* or *peak load,* is a term used in energy management to refer to a period in which electrical power is expected to be provided for a sustained period at a significantly higher than average supply level. These are periods such as the evenings, when many Americans are coming home from work and switching on their televisions and cooking dinner in their kitchens. Utility companies monitor peak demand very closely to determine how much energy is going to be needed at any point in time. There is an obvious design flaw with regard to solar, as the panels produce the majority of their electricity during the daytime, although many American in their homes use the most energy in the evenings or at night.

One potential solution to this, although complicated, is storage. As part of your solar array, you can choose to implement a storage system so that you can use the
electricity you produce during the day anytime you want. The current technologies available for storage and battery systems, however, are not very good. Solar has not become widespread enough to justify throwing money at companies to design and manufacture more efficient battery systems, so the price still remains extremely high. There is some hope, however, that with the help from investments in the electric vehicle industry, lithium ion prices have come down. Associated with that is the issue of what to do with the battery after it is used and how long it will last in the first place. Batteries contain numerous heavy metals and toxins that are harmful to the environment if they are not disposed of properly. Recycling batteries responsibly is sometimes difficult if the waste management provider in your area does not offer those services, or if you do not research where those batteries are going to be disposed of. Something that is all too common in the recycling of hazardous waste is the use of child and/or slave labor to remove the precious metals that are components of the battery’s system.

Besides battery storage for photovoltaic systems, another solution to peak demand could be a smart grid. A smart grid refers to a grid that utilizes digital communication and monitoring technologies to detect and react to changes in energy usage. Smart grids aim to find the gaps in energy supply and demand by improving our ability to predict when energy will be in high demand. Implementing smart grids would also allow the United States to make some much-needed improvements to the aging power grid.99 When our nation’s high voltage power transmission grid was being built back in the 1950s, no one could expect how large our population would be today, or how much power we would be using on a daily basis. The majority of our nation’s power grid was constructed

between the years of 1950 and 1970, with little improvements on the basic technology since.\textsuperscript{100} Black outs, brown outs, and power interruptions are occurring with increased frequency and cost the government, cities, and utility companies tremendous amounts of money when they occur.\textsuperscript{101} A modernized grid, with transmission facilities and power lines that can withstand our increased power usage and distribution for the foreseeable future, would likely reduce the probability of a major power outage, as well as pave the way for more alternative energy to be added to the grid.\textsuperscript{102}

\textit{What to do if you cannot go Solar: Energy Efficiency & Conservation}

While renewable energy is important for energy security and stability long term, energy efficiency and conservation are equally as crucial and can have a significant impact on reducing energy usage. By conserving energy we use less of it and using the energy that we need efficiently, we can also use less, and both of these can be done by a few simple behavioral changes that you can make on your own. It all begins with a comprehensive understanding of the impact that everyday decisions about consumption can have on the environment. Once one has that mindset, adopting sustainable practices as lifelong habits is easy.

Convincing homeowners to adopt energy conservation and efficiency techniques is surprisingly easy, as the incentive usually comes in the form of a lower utility bill. The first step is to cut down on energy usage altogether. This could manifest in a variety of forms, whether it be taking shorter showers, walking to work or using public

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\end{enumerate}
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transportation, or even choosing to turn off the television in the evening and read a book instead. It is estimated that the digital economy in the United States, which constitutes all digital forms of communication and entertainment, consumes an average of 1,500 terawatt-hours a year.\textsuperscript{103} While some forms of energy consumption are avoidable, others are not. For the energy that you do need, using it efficiently can also have significant impacts on reducing energy usage and wastage. Energy efficiency can take on a simple form, such as opting for LED light bulbs, which reduced the amount of energy that is wasted as heat by about eighty percent.\textsuperscript{104} It can also take on more expensive forms, such as opting for fuel-efficient or electrical vehicles. If you are interested in learning more about energy conservation and efficiency, there are many different resources available that making the switch to choosing more sustainable options easier and more approachable.\textsuperscript{105}

Discussions around renewable and alternative energy, as well as on sustainable in general, go beyond an immediate need but rather attempt to address the root cause of our environmental crisis and perhaps provide a solution for our changing climate. While energy conservation, efficiency, and renewable energy all can have an impact on improving sustainability and reducing our reliance on fossil fuels, simple actions such as opting for a solar system or choosing to walk to work are not going to have as significant of an impact as a market shift would have. Our free market economy has allowed for


fossil fuels to become entrenched in all modes of life, from production to transportation. There is, however, a silver lining to this, as many of the products we rely on are ripe for improvement. Take for example cars—there has been a dramatic change in fuel efficiency that occurred following the oil shocks of the 1970s.\textsuperscript{106} The technology was there, it just needed an economic push to make the technology affordable and widespread. Many hope that renewable energy will follow the same suit and become a necessary alternative when the negatives of our fossil fuel reliance become overbearing and too difficult to avoid. In order to make a significant impact, we have to change what feeds our economy. Consumption spurs economic growth, and as long as oil keeps flowing, the current United States economy will grow too.\textsuperscript{107}

\textsuperscript{107} James Gustave Speth, \textit{The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability} (New Haven: Yale University Press, 2008), 47.


**Part II: The Solar Industry Nationally & in Washington State**


Part III: The University of Puget Sound Solar Pilot Project

71. All of the information gathered about the considerations that needed to be made for rooftop solar on a university was gathered from conversations with the three solar companies we worked with from a period of June 2015 through April 2017. Those were Artisan Electric, Puget Sound Solar, and Sunset Air. Additionally, all information pertaining to Facilities Services at the University of Puget Sound has been shared with permission of the Associate Vice President, Robert Kief, and the Sustainability and Energy Manager, Alison Baur.

Part IV: Community Solar


73. All information regarding Community Solar was collected via a series of phone calls to the Washington State legislature in Olympia, Washington from the period of June 2016 through January 2017, unless otherwise noted.


76. All the information regarding the technical specifications of the Tacoma Power Community Solar project was gathered on a site visit in October 2016, unless otherwise noted.
Part V: Assessing the Effectiveness of the Community Solar Program


84. All the information regarding the technical specifications of the Tacoma Power Community Solar project was gathered on a site visit in October 2016, unless otherwise noted.


Part VI: The Future of Solar in Washington State


