Summer 2016

Community Distributed Solar Power: Advancing the Establishment of Solar Power in Pennsylvania

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Abstract

In the United States, community distributed solar has been highly successful when implemented; yet the country is stages behind leading users of solar such as Germany and Denmark. Distributed solar has generated income for owners of panels and developed into a sustainable energy model for those who can afford the initial cost. Many communities have explored different business models for implementing a solar photovoltaic (PV) system and have a wide range of reasons for desiring solar energy, such as the economic benefits of income and employment that are created and the positive environmental impacts and reduced emissions that are associated with renewable energy sources. This project aims to identify successful strategies for implementing a community distributed solar system by examining case studies from communities worldwide, with special attention to state and federal incentives for solar practices. Variables in successfully implemented community solar energy systems include financial incentives from the state and federal governments, the involvement of the community in developing the system, and the financial plan for cost-recovery (return on investment). Through surveying residents in central Pennsylvania, this project also seeks to understand what factors motivate or inhibit adoption of household and community solar energy systems, such as economic, environmental, and social factors. Since 2011, the cost of PV system installation has dropped by more than 60% (Schneider and Sargent 2014). This has made community solar more accessible to a wider range of communities with larger deviations in income. As the price continues to fall and the price of natural gas rises again, the market for community distributed solar may begin to flourish.

Key Words

Community distributed solar, photovoltaic (PV), renewable energy, environment

Introduction

All throughout the world, community distributed solar power is present. It exists in areas of different population densities, income, and development, with each case resulting in varying levels of success. In developing countries such as Brazil and India, the main intention when implementing a solar power system has been to electrify areas that are inaccessible to the national grid due to its geographic remoteness. By installing solar panels in these areas, communities are able to use renewable energy to assist in their daily activities, such as work, education, and cooking. Some communities, such as Indira Nagar in Rajasthan, India, heavily relied on kerosene lighting for electricity. Now the community pays a price for solar energy that was equivalent to the price they would pay for kerosene, but with immeasurable benefits associated with it (Hinds and Abdullah 2012). In the United States, the motivation has been economic and environmental implications. Under net metering, owners of solar panels can sell the excess energy that they produce back into the grid at the retail rate. In the two years following the American Recovery and Reinvestment Act (ARRA) of 2009, greater than 200,000 job years were created for construction with an additional 6,000 job years for operations and maintenance of PV and wind systems (Steinberg et al. 2012). This research inquiry aims to study past communities that have implemented solar power to identify vital factors that have made communities successful, and to use that information to further expand the possibility of spreading community distributed solar power throughout Pennsylvania.

Solar Energy in Pennsylvania

Community distributed solar describes the shared energy and results of a solar power plant by members of a community, rather than individual solar home systems, which are meant for only one household. Each member pays for shares of energy, which are received from the plant via an electrical grid. Members also receive financial benefits, such as those from the excess energy produced under the process of net metering. Other programs, such as the solar investment tax credit (ITC) and the 1603 Treasury Program, allow a portion of the installation costs to be financed by the federal government.

The future for solar energy in Pennsylvania is very optimistic. The National Renewable Energy Laboratory (NREL) estimates potential for 20 GW in rooftop solar PV in the state (Pennsylvania Department of Environmental Protection 2015). In 2008 another study by the NREL concluded that roughly 22-27% of homes are suitable for hosting a rooftop PV system (Coughlin et al. 2010). Problems concerning structure, ownership and visibility to the sun make this a realistic percentage. Due to the incapability of installing panels directly on some homes, many people initially rule out solar as their energy source. A community distributed system allows homeowners who are unable to install panels directly onto their property to have access to solar energy. Most communities that invest in shared solar have an offsite location, where a solar farm is created. It works akin to any other solar installation design but is connected to a microgrid, which transports electricity to the homes that choose to invest in the farm. For most homeowners, it makes solar power more accessible and a realistic alternative to other energy choices.

In May 2009, Pennsylvania enacted the Pennsylvania Sunshine Program, the state's most successful program at renewable energy investment. $113 million was invested, which generated $564.6 million in renewable energy investment by the end of the program in November 2013, when funds were exhausted. At the start of the program, Pennsylvania had less than 3 MW of solar PV; by the end the state had 200 MW, of which 98 MW was a direct result of the Sunshine Program (Pennsylvania Department of Environmental Protection 2014). The Department of Environmental Protection also reports that approximately 84,000 tons of carbon dioxide and an additional 525,000 pounds of sulfur oxides were displaced as a result of the program (Pennsylvania Department of Environmental Protection 2015).

Environmentally, solar panels produce 96% less pollution than coal-fired plants and 91% less than natural gas-fired plants. Pennsylvania is home to the country's largest natural gas field, the Marcellus Shale, which covers approximately 60% of the state. Natural gas output in 2015 exceeded 4.7 trillion cubic feet, ranking second in the United States only behind Texas. The state is one of the nation's top five largest coal producers, one of the top consumers of coal, and one of the top three generators of electricity (U.S. Energy Information Administration 2015). In 2013 alone, solar power in Pennsylvania grew by 39 MW and continues to be one of the most radical states at expanding solar (Schneider and Sargent 2014).

Literature Review

Intentions for Installing Solar

Globally, a core motivation for installing solar is in electrifying households, with much of the emphasis on solar home systems. Projects such as the Programa de Desenvolvimento Energético de Estados e Municipios (PRODEEM) in Brazil, directly involved solar home systems; however, compartia Energética de Minas Gerais (CEMIG), as a subproject of PRODEEM, did focus on electrifying individual households with solar systems. CEMIG also focused towards bringing power to communal structures, such as schools and health clinics, and providing water pumping powered by solar energy.

While most international programs focus towards electrifying remote, poor areas that were unable to be connected to the grid, some programs focused on the wealthier communities of these areas. Instituto para o Desenvolvimento de Energias Alternativas e da Auto Sustentabilidade (IDEAAS) in Brazil, Khmer Solar in Cambodia, and the hybrid system in the Inner Mongolian Autonomous Region in China tended to target the more affluent regions, which allowed the programs to be sustainable, as the customers are capable of making the payments for the systems and the companies are able to provide for the operations and maintenance needed for continual use of the systems. This revenue flow has made the solar systems reliable and efficient for those who can afford it. The problem, however, that these programs have faced is expansion. Due to the limited number of wealthy customers and vast number of those who cannot afford the system in the regions, it is difficult to expand through a consumer market model (Zerriffi 2011). Government subsidies and an increased use of cross-subsidization would be needed for IDEAAS, Khmer Solar, and the hybrid system in the Inner Mongolian Autonomous Region to expands its markets.

Programs in the United States have different intentions with communal electrification. Rather than supplying electrical needs to those with poor proximity to the national electric grid, programs in the United States use solar energy for its financial and environmental impacts. In all cases an array is created, either by a community or a cooperative. Most are in an open-field design, but some, University Park Community Solar, LLC, Greenhouse Solar Project with Appalachian Institute for Renewable Energy, Solar Pioneer II, Solar for Sakai with Community Energy Solutions, Mt. Pleasant Solar Cooperative, and the Orlando Utilities Commission Community Solar Farm are designed to be installed onto already standing constructs (Farrell

2010). Solar arrays are attached onto homes, churches, schools, and covered parking lots in these programs, giving the systems a favorable location by being structurally mounted rather than in a field or open space preventing other uses of the area.

Samso Island predominately used renewable resource systems for its environmental impacts. The federal government of Denmark set a goal of 200 MW of PV capacity by 2012, and by 2013 they more than doubled that figure, to 500 MW. By 2020 the desire 70% of the country's electricity coming from renewable sources; currently ⅓ of its electricity comes from wind alone. Lastly, by 2050 Denmark plans to be fossil fuel free, which Samso Island has been since 2007 (McLaren 2014). Most of the island's energy comes from its 21 wind turbines located both on land and in the water, while other energy is generated through individual solar home systems and generators powered by the combustion of hay (Godoy and Tierramerica 2009).

The Role of Government

A similar trend has been present with all of these characteristics so far. There is a noticeable distinction between actions done to supply power to inaccessible grid areas with the intention to provide basic electricity and actions done to convert to renewable sources to meet standards with the intention of environmental conservation practices. Many of the projects for poor, remote areas were developed by a centralized, governmental force, such as the Township Electrification Programme (China), PRODEEM (Brazil), and the Japanese PV/Hydro Project (Cambodia). The main issue with these projects was that there was no cost-recovery plan. They were financed by large initial government funds, but had no provisions for the future costs, causing necessary operations and maintenance to fail to occur leaving the systems inoperable. These programs did cover the large initial investment in the systems, but lacked the plans for continual funds to ensure the functioning of the systems. Centralized solar programs tended to fail due to its heavy reliance on the continuous support from donors. The Chinese Renewable Energy Development Project effectively balances the relationship between the central government and the program itself. The government pushes the project forwards and provides a small subsidy, but does not take control of the project entirely (Zerriffi 2011). By taking a secondary role by making the systems more affordable with small subsidies, the government has managed to allow the project to prosper and continue to function without dependence on donor funds from the state. The Gram Power project in Rajasthan, India also noticed similar effects. It was financed by modest government subsidies and private investment and works with the community to make the program effective. Credit is sold to a local entrepreneur who distributes allocation to community members. Gram Power also trains the community on the skills needed for operations and maintenance of the system, which is financed by revenue collected monthly (Hinds and Abdullah 2012). This allows it to be a self-sustaining model within the community.

In the United States, decentralized systems are more common. While most are funded in some way or another by a federal or state program, all projects require customers to cover most of the costs of the systems, allowing for a revenue stream used for operations and maintenance costs. One problem with this, however, is green pricing. This has come up in Sol Partners with United Power, Greenhouse Solar Project with Appalachian Institute for Renewable Energy, Solar Pioneer II, SunSmart, the Ellensburg Community Solar Project, and the Orlando Utilities Commission Community Solar Farm. This results in customers paying a premium for the systems, usually with a very lengthy time on their return. The lease agreed upon with the utility expires before they recover their initial investment. For example, the Solar Pioneer II in Ashland, Oregon has a lease that lasts for 20 years, while the estimated year for payback is 30-34 years with electricity inflation of 2-3%. Part of this green pricing is due to the inability to receive federal ITC for the project. Instead, the project was funded by clean renewable energy bonds (CREBs) and small $2.25/W rebates capped at $7,500 per customer. Had the project been an individually owned one rather than a communal effort, the project would receive the 30% federal ITC and $3/W rebate capped at $6,000 per customer. This would have cut the payback time nearly in half (Farrell 2010). Although this project is quite expensive for customers, it produces fewer emissions and is environmentally efficient, thus a rational investment for those concerned with the state of the world's environment. It can also reduce electrical costs over the long term, making it important for individuals looking for an alternative solution to flattening their electrical bills.

In Denmark, Samso Island has been self-sufficient since 2003. In the beginning stages of developing itself as a model for a renewable energy society, Samso Island received funds to finance some of the capital costs of the generators, turbines, and some smaller household projects from the Danish Energy Authority. Although funds diminished by the early 2000's, the role of the government helped to convince the residents to continue to invest in renewable energy systems even after funds were eliminated. All of the recent renewable energy projects have been funded by the island residents, not through government subsidies. The ownership of the biomass generators, windmills, and solar home systems has been planned so that the residents could take full initiative in the project and only rely on themselves for sustainability. This has made Samso Island an excellent example of a highly successful project without large support from a centralized, governmental actor.

Methods

Data was collected by examining case studies from communities worldwide. Each community is analyzed by focusing on certain variables, such as the financial incentives from state and federal governments, the involvement of the community and of the central government in developing the system, and the financial plan for cost-recovery or return on investment of the system.

A short survey was conducted at three locations in central Pennsylvania. From July 13-July 19, we collected a convenience sample survey at the Lewisburg Farmers' Market (Union County), the Sunbury Market House (Northumberland County), and the Middleburg Livestock Auction (Snyder County). The survey consisted of four sections: demographic information, reasons for installing or considering to install panels, community distributed solar power, and personal beliefs on global change. Respondents used a likert-scale model to give an answer, ranging from 1-5, based on the question.

A total of 22 surveys were collected, with the demographic sample by county represented in Figure 1. Of those surveyed, 7 were male, 15 were female ranging in age from 36 to 83 with the average age of respondent being 63. All respondents were property owners of single-family homes, except for one property owner who owns a farm. Of the respondents, 2 had installed solar panels on their property; both were attached onto their roofs.

Results were analyzed using correlations to determine associations between likert-scale responses and T-tests to determine statistical significance between populations.

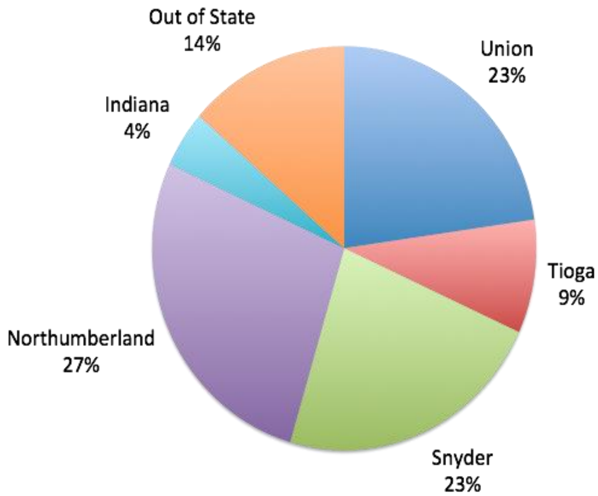

Figure 1. Sample by County of Residence

Results

The initial prediction for the results collected, now in Table 1, was that the option "Financial Affordability" would have the highest average when subjects were asked "When thinking about why you installed, or would consider installing, solar panels on your property, how important are each of the following factors". Although solar energy costs have dropped in the recent years, it is still expensive for the average citizen, which has made us predict that most subjects would score that factor as the highest.

Of the 22 subjects, only 5 considered themselves "somewhat familiar", "moderately familiar", or "extremely familiar" with community distributed solar systems, corresponding to a 3,4, or 5 on the scale. Although a majority of respondents were not familiar, as shown in the 2.05 average in Table 2, it was indicated that both community and individual systems were desired.

Despite respondents generally are not knowledgeable of community distributed solar systems they are still desirable of such systems. This corresponds to the high levels of importance and concern given to issues on climate change, represented in Table 3. Every subject responded that it was at least "somewhat important" to reduce their personal energy consumption, corresponding to a 3 on the scale.

Table 1. Factors Towards Installing Solar Panels

When thinking about why you installed, or would consider installing, solar panels on your property, how important are each of the following factors?	Average
Financial Affordability	3.95
Environmental Impacts	4.55
Reduces Greenhouse Gas Emissions	4.55
Energy Independence	4.45
Economic Benefits (i.e. employment, income)	4.23
Geography/Location	4.09
Health Reasons	3.86
Federal/State Incentives	4.32
Friends/Neighbors have solar panels installed	2.27

Table 2. Community Distributed Solar

Community Distributed Solar	Average
Familiarity with community distributed solar	2.05
Level of desirability for community distributed solar system	3.91
Level of desirability for individual installation of system (single solar home system)	4

Table 3. Personal Beliefs on Global Climate Change

Personal Beliefs on Global Climate Change	Average
How concerned are you with climate change currently?	4.18
How important do you believe it is to achieve energy independence?	4.5
How important is it for you to reduce your personal energy consumption?	4.55
How important is it for the United States to reduce its energy consumption as a nation?	4.45
I would pay more for solar energy, even if it is more expensive than typical electricity	3.64

After analyzing the survey data, it was found that the variables “Environmental impact is important to me when considering installing solar panels on my property” and “How important is it for the United States to reduce its energy consumption as a nation?” have the strongest relationship. The correlation coefficient, $r=0.86$, indicates that the two variables have a strong positive association. This means that a respondent who thinks that the environmental impact of installing a solar power system is important is likely to think that it is important for the United States to reduce its energy consumption. Interestingly, the variables “Environmental Impact is important to me when considering installing solar panels on my property" and "How important is it for you to reduce your personal energy consumption?" have a correlation coefficient of 0.31, which is moderately positive but much weaker than the relationship previously explained. Other variables with a noticeable relationship are "How concerned are you with climate change currently?" and "I would pay more for solar energy, even if it is more expensive than typical electricity" with a correlation coefficient of 0.3. This represents a moderately positive relationship between the two variables and explains that people who are more concerned with climate change would be more likely to pay for solar energy, regardless of whether it would cost them more. Two variables were found to have a moderately negative relationship with a coefficient of -0.41: "Financial affordability is important to me when considering installing solar panels on my property" and "I would pay more for solar energy, even if it is more expensive than typical electricity" (see Table 4). This means that someone who finds affordability as an important factor when wanting to install solar will be less likely to pay for solar if it will cost him or her more than his or her typical electrical source. These results could explain why many people are worried about the environment but may not be inclined to yield to green pricing.

Table 4. Correlations Between Variables

Variable 1	Variable 2	Correlation Coefficient	Relationship
Environmental impact is important to me when considering installing solar panels on my property	How important is it for the United States to reduce its energy consumption as a nation?	0.86	Strongly positive
Environmental impact is important to me when considering installing solar panels on my property	How important is it for you to reduce your personal energy consumption?	0.31	Moderately positive
How concerned are you with climate change currently?	I would pay more for solar energy, even if it is more expensive than typical electricity	0.3	Moderately positive
Financial affordability is important to me when considering installing solar panels on my property	I would pay more for solar energy, even if it is more expensive than typical electricity	-0.41	Moderately negative

T-Tests were conducted to compare counties on factors, however the sample size was too small to develop meaningful comparisons. For the T-Tests conducted, there was only one statistically significant result. A p-value of 0.034 was found for the variable "Federal/State Incentives is important to me when considering installing solar panels on my property" for Union and Snyder counties. This result shows a statistical difference for the variable that was unique to only these two counties.

Discussion

The most successful communities at using a distributed solar power system have been in developed countries. In most cases, customers have to agree to green pricing initially, allowing for installation, operations, and maintenance costs to be covered for a few years before return on investment is generated. In developing countries that have implemented solar programs, such as Brazil and Cambodia, the government has largely funded the projects. This centralized effort has covered the costs for installation but failed to make any provisions for the future, which has caused the projects to cave-in on themselves due to lack of finances and training for continued operation. Projects in the United States, such as the Keystone Solar Project, and in other developed nations, such as the 100% self-sufficient and clean Samso Island of Denmark, have been successful by implementing partial federal support initially; gradually the government removes its support, allowing the communities to take full control of the project.

As was noticed in observing the case studies from across the United States, the main focus towards solar implementation has been an environmental one from analyzing the data above. Most people felt that the environmental impacts associated with solar energy are more important that the financial impacts, primarily the affordability of the system. Two other strong factors were energy independence and energy consumption, both individually and nationally. In the United States, 29 states, Washington, DC and two territories have enacted an Alternative Energy Portfolio Standard. This requires all electric supplying companies to supply a noted percentage of its electricity from alternative energy sources by a given year. In Pennsylvania the requirement is 18% by 2020, with 8% from Tier 1 technology (solar, wind, thermal, low-impact hydro, biomass), where 0.5% is from PV, and the remaining 10% from Tier 2 technology (high-impact hydro, waste coal, municipal solid waste) (Database of State Incentives for Renewables & Efficiency 2016). Governor Tom Wolf of Pennsylvania has supported bills to increase the standard to 15% required from Tier 1 technology and 1.5% from PV, however no progress has been made at passing these bills (Pennsylvania Department of Environmental Protection 2015).

One community has fully achieved energy independence in the course of only a decade; Samso Island, a municipality located in the North Sea off the coast of Denmark, which began self-supplying their energy in 1997 after being chosen as Denmark's model for renewable energy. By 2005, the island had a net positive budget of energy consisting of 21 windmills, 4 hay combusting generators, 3 district-heating plants, residential solar panels, biomass boilers, and even heating transfer systems using milk to generate heat. In 1997, Samso was completely reliant on coal and petroleum, but since 2007 the island has not produced any greenhouse gases. The residents of Samso Island were able to successfully implement renewable energy into every aspect of their lives by taking on an active role in financing and installing the diverse type of systems. The total cost was relatively high, 425 million Danish Krone (approximately US $64 million), although a portion was covered by the Danish Energy Authority (PlanEnergi & Samsø Energy Academy 2007). Even with this burdensome cost, the island was able to make a swift return due to its energy efficiency and tourism that evolved as the island continued to make energy improvements. The profits accumulated by the municipality helped construct the Energy Academy, where people worldwide gather to be educated on renewable practices that have made Samso so prosperous. Mainland Denmark has also set high goals of energy independence, as noted above. Finally, Denmark aims to be fossil fuel free by 2050, but by observing their achievements currently they may reach that milestone much sooner than predicted (McLaren 2014).

Data analysis for this project could be improved if the survey sample size is increased. Surveying subjects in person possibly could have been hindered by the nature of surveys. Throughout surveying, many people seemed disinterested almost instantly when asked if they would be interested in taking a survey. This could be corrected if an online survey was sent out to a large population or there was an incentive offered to subjects, such as a discount to a local store. Another improvement that could be made would be to diversify the sample. An online survey could branch out to a larger pool of demographics to acquire different perspectives of socioeconomics from around the state or country. By having a bigger sample size, it could pave way for interviewing individuals, communities, and businesses that have installed solar panels on their property or pay for solar in other means.

Solar power in the United States can tremendously advance if the public is made more aware of the advantages of a community distributed system and the financial incentives provided by the government and some electric utilities. When implemented successfully, solar power can provide excellent benefits, from generating income to producing close-to-no emissions. Further research and sampling, in addition to new policies and standards that promote the use of renewable energy technology, will be able to further educate the nation on the importance and accessibility of solar power, assisting in its advancement.

Acknowledgments

I would like to thank Bucknell University, the Bucknell Institute for Public Policy, and the Place Studies Program for their support on this research. I would also like to acknowledge Dr. Shaunna Barnhart, my faculty mentor, on her valuable help and constructive assistance throughout the duration of this project.

Appendices

Appendix A- Background and Comparative Research

Zerriffi 2011

- Rural electrification tends to be associated with poorer/less developed communities with low consumption habits
  - Makes financing the service more difficult
- Electricity for social/welfare purposes (schools, health clinics) is commonly lagged behind electricity in homes (noticed in these rural areas)
  - Energy expenditures in homes aimed to hover below 15%, in some productive activities (these social programs) energy expenditures can be close to 50% of production costs
- Case Studies
  - Kenya
    - Began as donor program→ formed into private company
  - Brazil
    - Companhia de Electricidade do Estado da Bahia (COELBA) in Bahia
      - System maintained by Companhia Energética do Amazonas (CEAM)
      - Customers pay reduced tariff
      - Diverse mix of customers makes cross-subsidization easier (wealthier customers pay more to cover for poorer customers)
      - High potential for systems in Brazil (remoteness, solar insolation)
      - With subsidy tariff= R$ 2/month, without = R$ 20/month (13 kWh/month-- covers only basic electrical needs)
      - 2000 study- 170,000 systems w/o subsidy
        - w/ 30% subsidy→ 50% more households could afford it
      - Subsidies from Luz Para Todos program (2003) and cross-subsidies
      - *STRENGTHS:* electricity to those who need it, government subsidies make it more affordable, geographic location, cross-subsidization, funds from Luz Para Todos
      - *WEAKNESSES:* limited electricity (13 kWh/month), only one-sized systems
    - compartia Energética de Minas Gerais (CEMIG) in Minas Gerais- 1996
      - Part of PRODEEM
      - CEMIG covered ⅔ of costs, municipality in community other ⅓
      - Customers pay flat monthly fee to cover battery replacement, CEMIG ended up paying other costs (operations, maintenance)
      - 1995-2001: only 450 of 4700 expected solar home systems (10% of its goal)
      - *STRENGTHS:* plan for school electrification (4,700 using PV)
      - *WEAKNESSES:* CEMIG covered more costs than anticipated (90% rather than 64%)
    - The Programa de Desenvolvimento Energético de Estados e Municipios (PRODEEM)- established in 1994

            - Use of renewable resources for communities (schools, health clinics, etc.)
            - Mixed results (8,700 installed systems)-- but some equipment/logistical problems causing systems to not work in a few years (undersized inverters, difficulty in changing battery, lack of revenue flow)
            - *STRENGTHS:* good intentions (communal structures), free of charge to communities
            - *WEAKNESSES:* poorly chosen equipment (undersized inverters), little provision for operations and maintenance (no way to finance/handle), no cost-recovery plan→ unsustainable, minimal community involvement
        - Instituto para o Desenvolvimento de Energias Alternativas e da Auto Sustentabilidade (IDEAAS) w/ STA
            - Joint operation with partnering company (STA)
            - Customers pay installation fee and flat monthly fee (based on size)
            - Targets wealthier customers
            - *STRENGTHS:* three size options offered (60, 90, 120 W)
            - *WEAKNESSES:* the sizes are higher than centralized programs but still relatively limiting in power supplied, target high income households (meaning their customers are limited)
        - 32 solar battery charging stations installed by Golden Genesis and Companhia Paranaense de Energia (COPEL)
            - Failed- poor battery quality/lifetime, difficulty to get to stations for some customers
        - Agência Nacional de Energia Elétrica (ANEEL)
            - Concession system (like U.S.)
            - Regulates Brazil's electricity
    - Cambodia
        - Small solar home systems (for wealthy population)
        - Provided by Khmer Solar (1997) in Phnom Penh and Battambang
            - Most common system is 85 W for $750 (2x per capita GDP at the time)
            - Relatively small market
                - Most civilians can't afford it (Battambang is a wealthier area)
                - 50% import tariff on solar panels has made it more difficult to purchase them (prevents cost reduction)
            - Also provides similar solar systems to NGOs for projects (schools, etc.)
            - Customers are actually covering the majority of costs of the system (contrast to CEMIG in Brazil)-- makes it more sustainable system
            - Reliable systems for those that can afford it

            - *STRENGTHS:* one-year warranty, reliable and efficient for those who can afford it, full cost-recovery (willingness for Cambodians to pay for electricity)
            - *WEAKNESSES:* warranty is very short amount of time, 50% import tariff on solar panels (makes it more expensive), limited market→ difficulty in expanding to other areas because of the systems' expensive costs
        - Japanese PV/Hydro Project
            - $3 million project- combination of PV and hydro mini grids, 5 satellite PV battery charging stations
            - Provided to 410 homes at 16 c/kW (too low to cover operations/maintenance costs so 25 c/kW proposed)
            - Electricity only provided from 6-9pm
            - Both the PV system and hydro system broke down quickly (with no money to fix it)
                - Revolving door→ no money to replace system, unable to collect tariff when no power is supplied
            - *STRENGTHS:* international aid
            - *WEAKNESSES:* electricity only provided from 6-9pm, tariff is too low to recover costs, both the PV and hybrid systems broke down (w/ no replacement funds collected), only serves one community (400 homes), too reliant on donor funds
    - China
        - wind/solar hybrid systems (for wealthy population-expensive)
            - Inner Mongolian Autonomous Region
            - 8400 installed by 2004
            - 400-500 W system (large)
            - 2004 study found 50% of systems in good condition, 36% experienced periodic failures, 15% in bad condition
            - *STRENGTHS:* wind system- successful (favorable wind conditions, small subsidy for capital costs); hybrid system- large sized (could meet household needs, summer refrigeration), higher subsidy (30%) than wind system
            - *WEAKNESSES:* wind system- (50 and 100 W) expensive, suffered in summer weather conditions (less wind); hybrid system- expensive (10,000 yuan), poor quality inverters, short battery life
        - Township Electrification Program (TEP)-- 2002 (part of the National Development and Reform Commission)
            - Electrified 1061 villages (~1 million people) in only 3 years
                - Combination of (mainly) hydropower (378 villages, 200 MW out of 220 MW total), PV (666 villages) and PV/wind hybrid (17 villages)
            - Covered by large central government funds

            - Successful at providing short term needs but doesn't have any provisions for the future or cost recovery practices
            - *STRENGTHS:* provided short-term needs, central government power helped electrify over 1,000 villages in 3 years
            - *WEAKNESSES:* no cost-recovery plans, lack of clear ownership after 3-year coverage (no system to put localize ownership)
        - Small solar home systems-- China Renewable Energy Development Project (REDP)- 1999
            - One of the largest markets for SHSs
            - Mostly prevalent in western China where access to grids is limited
            - Small systems which made it more affordable
            - Pushed ahead by government
            - *STRENGTHS:* targeted customers unable to access grid, small (affordable) system, modest subsidy
            - *WEAKNESSES:* limited power (but generally able to meet most needs)
        - China has seen success in rural electrification efforts when the central government takes a secondary role by working with policies and regulations-- helps sustainability, technology development, quality, cost reductions, uses low interest loans, protective policies
        - China has struggled when the central government takes a more direct and controlling approach (ex: Township Electrification Program)
        - Hasn't turned to renewable sources for its environmental benefit, but rather for its convenient geographic location
    - India
        - Ministry of New and Renewable Energy
        - cross-subsidies insufficient to cover the costs
    - "rural electrification efforts fail to live up to the needs because utilities view it as a liability while proponents (including within the international community) view it too often as charity (161)"
- Possible government actions to promote rural electrification:
    - Modest subsidies, tax reduction, protection laws/acts, electrification beyond basic needs (more for productive activities too)
- Important factors to consider:
    - Customer willingness and ability to pay fees/costs
    - Project's reliance on subsidy (should have constant revenue flow so that its existence doesn't depend on subsidy)
    - If decentralized, community members must be trained in maintenance procedures
    - Link rural electrification with rural development
    - Subsidies can sometimes impact wealthier more than poor (poor may not be able to purchase system and have low consumption--many subsidies are based on consumption)

        - Goal should be to move to more modern energy system (help with the initial costs to steer in right direction)
        - Subsidies should have an expiration date (to avoid dependence)
- Some government programs have created renewable energy systems, but have failed to create a sustainable system in the long run
    - Ex: Zimbabwe created many photovoltaic (PV) systems funded by government program→ all failed when the funds stopped coming in (and no provisions to push system towards a more market-friendly operating system)
        - Subsidies have positives (creates system) and negatives (makes system completely dependent on funds) noticed in this case
- Relationship between electricity and development
- Variables studied in this literature
    - Independent: Organization Form (centralized or decentralized organization, government or nongovernment) , Technology Choice (renewable or nonrenewable, minigrid or individual system, Target Customers (household or community), Financial Structure (how capital is acquired, how operation costs covered)
        - Centralized, Gov: Ministry of New and Renewable Energy (India), PRODEEM Programme (Brazil), Township Electrification Programme (China)
        - Centralized, non-Gov: concession systems (U.S.)
        - Decentralized, non-Gov: small PV systems (western China, Kenya), co-ops (U.S., Philippines)
    - Dependent: Changes in Electricity Service, Sustainability, Replicability
    - Control: remoteness of customers, density of customers, capital and operating cost subsidies, policy regime, regulatory regime
- Policies/Laws
    - Concession system: company licensed to provide power to region and must abide by regulations and tariffs, like a contract
- Cross-subsidies can be effective if it doesn't put a heavy reliance on the donor and they are re-negotiated frequently to adjust to the changes in financial position

Coelba 2016

"Photovoltaic systems, such boards to be examined in new certification laboratory solar cells, are capable of generating electricity through photovoltaic cells calls. These cells are made of materials capable of transforming solar radiation directly into electricity through the so-called "photovoltaic effect" that happens when sunlight through its photon is absorbed by the photovoltaic cell. The energy of light photons is transferred to the electrons that then gain the ability to move. Thus, the movement of electrons generates electric current. Currently, the most widely used material in the production of the panels is silicon."

Hinds and Abdullah 2012

- Solar Electric Light Company (SELCO)- Karnataka, India
    - Aided over 120,000 families
    - Adapts systems based off of the poor
- Indira Nagar, Rajasthan, India

    - 240 W solar power plant by Minda NextGenTech Ltd
    - Each house pays 150 Rupees/month
        - Maintains power plant, generates ROI for future power needs
    - Noticed improvements in education, work (mainly sewing and pulse grinding) and sustainability
    - *STRENGTHS:* positive externalities (education, income-generating/leisure work-women especially), little financial impact on families-- 150 rupees/month was virtually the same they paid for kerosene
    - *WEAKNESSES:* small system for a community (240 W distributed among 13 homes- 190 people)
- Gram Power
    - Micro-grid system providing power to homes within 2km radius
    - Funded through government subsidies and private investment
    - Energy credit sold to local entrepreneur who sells prepaid power allocations to consumers (similar to a parking meter)
        - Revenues collected pay for system's operations, maintenance, capital recovery (self sufficient model)
    - Gram Power trains community on system maintenance
    - Demand driven model (consumers see their consumption levels and strive to be conservative about their energy use)
    - First project in Rajasthan in May 2012
        - ~84% energy savings
        - 0.4 kWh/day for the average consumer
    - Strays away from subsidized tariffs, focuses on monthly expenditures
    - *STRENGTHS:* cost-recovery, trains community useful operation skills, funded through government subsidies and private investment, customers know their exact consumption level (shown on a meter), local entrepreneur given skills to sell the power to public (earns 10% of every sale), smart micro-grid designed to prevent theft, on-demand power, 84% energy savings (0.4 kWh/day used rather than 2.4 kWh/day normally)
    - *WEAKNESSES:* cultural aspects (needs approval from panchayat)
- Scatec Solar-- private–public–people partnership (PPPP) model
    - 28 villages in four states in India: Uttar Pradesh, Madhya Pradesh, Jharkhand, and Jammu and Kashmir
    - 290 kWp, 1300 families in total
    - Partnered with MNRE and Norad (The Norwegian Agency for Development Cooperation) for funding and IREDA (Indian Renewable Energy Development Agency) for monitoring
    - Worked with local NGOs to educate villages on PPPP and carried out need assessment
        - Created village energy committees to elect individuals capable of operating the systems

- *STRENGTHS:* bottom-up approach, formed village committees and system operators who would be trained, externalities (water pumping, education, health, cooking)
- *WEAKNESSES:* not coordinated with local government, can get expensive

Enersol 2009

- Solar Based Rural Electrification Concept (SO-BASEC)- an Enersol (Massachusetts-based) program based in Bella Vista, Dominican Republic- 1988-- 48 Wp
  - Low cost micro-credit plan over the course of many months (roughly equal to what they previously would pay for kerosene lighting)
  - Provided training to local businesses selected to supply system
  - Soon spread to the rest of the nation and a second SO-BASEC program in Honduras

Covell 1990

- SO-BASEC program in Bella Vista and Puerto Plata
  - $200-$500/system (pays for itself in 5 years)
    - Rural credit companies required to spread payments
  - More than 1,000 systems installed nationwide by 1990

  - *STRENGTHS:* international aid, trained local technicians
  - *WEAKNESSES:* relies on funds and donors for support (governments too)

Grameen Shakti 2016

- Over 1.6 million SHSs installed by 2015
- Positive externalities-- more income for businesses (extended hours), work for women
- Micro-grid utility has provided business owners to share SHS power amongst themselves
- SHS powered Polli Phone (off-grid telecommunications)

Komatsu et al. 2011

- Grameen Shakti (Bangladesh)- 1996
  - Provides credit for SHS purchase
    - Created network of entrepreneurs to install services
    - Over 317,000 SHSs installed by 2009, unsubsidized, affordable loan system
    - Customers pay upfront payment of 15-25% of total cost, pay rest in 2-3 years (at 6-8% interest)
  - Factors found to determine buying SHS (besides income)
    - Number of rechargeable batteries, high kerosene consumption, ownership of many cell phones

    - Factors found to determine SHS size option
        - House income, kerosene consumption, number of children, demand for lighting, concern for indoor pollution (health risks associated with kerosene use indoors)
    - *STRENGTHS:* focused on communities without access to supply grid, multiple sizes offered (40, 50, 65, 85, 120, 130 Wp-- $328-$991) as of January 2009
    - *WEAKNESSES:* limited generation capacity (can only use devices at low outputs)

Hallock and Sargent [2015]

- Price of typical PV system has declined 6-8% annually on average since 1998 (according to the National Renewable Energy Laboratory)
- Net metering policy: owners of systems are credited for their surplus energy absorbed
    - Customers pay for electricity consumed minus electricity produced
- “Value of solar” policies: customers paid a rate based on the estimated beneficial value supplied to the grid
    - Can be calculated by summing up the avoided costs (energy costs, capacity and capital investment, costs of market price fluctuation and environmental compliance costs)
    - Commonly, value of solar is greater than the retail electricity rate (which is the rate owners are compensated with)
    - Ex: Minnesota’s “value of solar tariff”
- Less volatility in price (onsite production helps to ensure price stability)
- Renewable electricity standards (state and federal)
- Solar installation in Scranton, Pa

Coughlin et al. [2010]

- 2008 study- only 22-27% of homes are suitable for hosting rooftop PV system (due to ownership, structural and shading reasons)
- Community Project Models:
    - Utility-sponsored-- community/group doesn’t own systems, contract with utility who sells the energy to group
        - Ex: Sacramento Municipal Utility District with enXco (SolarShares program)
    - Special Purpose Entity (SPE)- business with narrow-minded/limited goals
        - Ex: Clean Energy Collective, LLC (Colorado)-- 78 kW
    - Non-profit organizations cannot receive tax credits, but donors for non-profit projects can receive tax deductions (tax deduction is less in value than tax credit)
        - Ex: Community Energy Solutions (Sakai, Washington)- for middle school
- 1603 Treasury Program- grant to applicants to reimburse them for partial cost (in lieu of ITC)- also 30%
    - Not applicable to non-profit organizations or government entities

    - *many deadlines to be aware of
- Power Purchase Agreement (PPA)- agreement between energy provider and utility
- Solar Services Agreement (SSA)- agreement between system owner and system site host (owner provides maintenance services to ensure continued solar power provision)
- Renewable Energy Tax Credit not applicable to community projects because it requires taxpayers to install system directly onto their home
- Modified Accelerated Cost Recovery System (MACRS)- tax deductions based off of depreciation of investment (not applicable to individuals)
- Tax credit bonds- for non-taxpayers (government entities, co-ops, municipal utilities)
- **Database of State Incentives for Renewables & Efficiency 2015**
    - Clean Renewable Energy Bonds (CREBs)- used to finance renewable energy projects
    - Qualified Energy Conservation Bonds (QECBs)- same has CREBs but also can be used for energy efficiency projects/green community projects
- Project Steps:
    - Feasibility, project development, construction, operations and maintenance, decommissioning (exit strategy-long term)
    - Sample budget/checklist on page 36 of US DOE saved pdf

Nielsen and Jørgensen 2015
- Samso Island
- Process of self-supplying energy began in 1997
    - By 2005 the island had a net positive budget of energy (produced more than they consumed)
- Population of just above 4,000 with about 350,000 coming in the summer months
- 21 windmills (11 onshore 1 MW, 10 offshore 2.3 MW)

Kuang et al. 2016
- Solar water heating (SWH) systems are widely used in islands
    - In Cyprus 92% of families and 53% of hotels have SWHs
- PV systems require large initial investment and prone to damage from changing climate
    - Big in Pellworm (island off the coast of Germany)
- Some renewable systems are weather-dependent (sunnier in summer, windier in winter) creating obstacles (and innovation such as hybrid systems, smart grids, energy storage, etc.)

Godoy and Tierramerica 2009
- 114 sq. km island
- 4 generators running off of hay combustion (abundant resource on island)
    - Generators produce both heat and electricity
- Island was 100% reliant on coal and petroleum in 1997
    - By 2003 the island was self-sufficient
    - Hasn’t produced any greenhouse gases since 2007
- Important part was the vast participation by residents

    - Privately owned turbines, solar panels
- Dairy farmers have used a heating transfer system too with milk production
    - Transfer of heat from milk to their homes

McLaren 2014
- Roughly 75% of of Samso's heating comes from solar and biomass energy
- Denmark government goals
    - By 2012: 200 MW of PV capacity
        - By 2013, 500 MW of PV systems were installed
    - By 2050, fossil-fuel free
    - By 2020, 70% of energy from renewable sources
        - Currently more than ⅓ of electricity from wind

PlanEnergi & Samsø Energy Academy 2007
- 11-1 MW wind turbines= 66 million DKK (8.8 million Euros)
- 10-2.3 MW wind turbines= 250 million DKK (33.3 million Euros)
    - Danish Energy Authority funded 7.5 million DKK (1 million Euro)
- 3 district heating plants= 45 million DKK (6 million Euros)
    - Danish Energy Authority funded 12.5 million DKK (1.93 million Euros)
- 300+ homeowners/businesses invested 15 million DKK (2 million Euros) in renewable energy technologies
    - Danish Energy Authority funded 3 million DKK (400,000 Euros)
- Total investment= 425 million DKK (57 million Euros)-- DEA covered some of these costs
- 1997-2001: subsidy programs→ solar thermal panels (up to 30%), biomass boilers (up to 20%), heat unit pumps (up to 15%)
- BUT, transportation has not been reduced, nor switched to renewable energy

Samso Island
- *STRENGTHS:* net positive energy budget, resident-owned systems, good mix of renewable sources, island (separated from mainland)
- *WEAKNESSES:* some systems are weather dependent (so they diversify the systems)

Farrell 2010
- Clean Energy Collective (Colorado) w/ Holy Cross Energy- 2010
    - 77.7 kW system for $466,000 ($6/W)
    - Received federal tax credit (30%)
    - $725/panel (230 W) with 340 total panels (18 owners)-- 50 year lease
    - Owners receive $0.11/kW produced--negotiated PPA ($0.105 for retail rate)
    - Estimated 13-15 year payback (5% and 2% electricity inflation)
    - *STRENGTHS:* solar ITC, owners receive more than retail rate, good payback return, good location ("otherwise unusable land")
    - *WEAKNESSES:*
- Sol Partners (Colorado) w/ United Power- 2010

- 10 kW system for $120,000 ($12/W)
- Did not receive federal tax credit
  - Receive $50,000 grant from governor
- $1,050/panel (210 W)-- 25 year lease
- High capital costs (estimated $32/year/panel of generated credit)
- Estimated 20-26 year payback (5% and 2% electricity inflation)
- *Lease expires before initial investment recovered
  - "Pre-paid green pricing"
- *STRENGTHS:* received grant that is more valuable than the solar ITC
- *WEAKNESSES:* high capital costs, pre-paid green pricing

- Florida Keys Electric Cooperative (FKEC) Simple Solar Program- 2008
  - 96.6 kW system
  - Received cleaned renewable energy bonds (CREBs)
  - $999/panel (175 W)-- 25 year lease
  - Estimated 21-23 year payback (3% and 2% electricity inflation)
  - *STRENGTHS:* CREBs, more affordable than individual ownership
  - *WEAKNESSES:* relies on CREBs
- University Park Community Solar, LLC (Maryland)
  - 22 kW system for $126,000 ($5.75/W)
  - Received federal tax credit (30%)
  - Sale of electricity to church= $0.13/kWh
  - Sale of SRECs=$0.25/kWh
  - Private enterprise→ must comply with SEC's investor regulations
    - Can have no more than 35 investors
    - Cannot advertise (must be word-of-mouth)
  - Estimated 5 year payback (2% electricity inflation)
  - *STRENGTHS:* built on existing structure, SRECs, solar ITC, good payback return, affordable
  - *WEAKNESSES:* private enterprise rules and restrictions
- Appalachian Institute for Renewable Energy Greenhouse Solar Project (North Carolina)
  - 2.4 kW system for about $20,000 ($8.34/W)
  - Received federal and state tax credits (NC has 35% credit)
  - Sale to AIRE building under PPA=$0.10/kWh
  - Estimated 13 year payback
  - *STRENGTHS:* state credit and solar ITC, built on existing structure
  - *WEAKNESSES:* small project, owner of structure must comply to green pricing
- Solar Pioneer II (Oregon)
  - 64 kW system for $442,000 ($6.91/W)
  - 175 W panels w/ 363 in total-- 20 year lease
  - Received CREBs
  - Estimated 30-34 year payback (3% and 2% electricity inflation) for community project investment

        - *estimated 16-17 year payback (3% and 2$ electricity inflation) for individually owned system (city/state incentives only available to individuals)
    - *Lease expires before initial investment recovered
        - "Pre-paid green pricing"
    - *STRENGTHS:* CREBs, built on existing structure
    - *WEAKNESSES:* pre-paid green pricing, more expensive than individual ownership
- SunSmart (Utah)
    - 100 kW system
    - $3000/panel (500 W)--$6/W up to 4000 W--- 19 year lease
    - Received state tax credit of 25% (up to $2,000)
    - Estimated 32 year payback (2% electricity inflation)
    - *Lease expires before initial investment recovered
        - "Pre-paid green pricing"
    - *STRENGTHS:* state tax credit
    - *WEAKNESSES:* pre-paid green pricing, depends on altruistic community members to invest
    - **Solar Washington [2014]**
    - Currently 111 kW total
        - 192 modules, 720 thin-film modules
- Ellensburg Community Solar Project (Washington)-2006-08
    - 58 kW (phase one: 36 kW; phase two: 22 kW)
    - 73 investors-- paying for prepaid block of electricity (paying a premium)
    - Base rate community solar $0.30/kWh
    - Estimated 8 year payback (2% electricity inflation)
    - *STRENGTHS:* state incentive ($0.30/kWh), good payback return
    - *WEAKNESSES:* customers pay a premium (more than typical electricity)
- Solar for Sakai w/ Community Energy Solutions (Washington)- 2009
    - 5.1 kW system for $50,000
        - Produces 6,120 kWh/year
    - State production incentive= $0.15/kWh
    - Donors do not get ownership (simply charitable)
    - *STRENGTHS:* net metering credit, state production incentive ($0.15/kWh), $7,500 grant, built on existing structure (school)
    - *WEAKNESSES:* donors don't get ownership, expensive
    - **Bainbridge Island Review [2008]**
        - 30 panels
- Mt. Pleasant Solar Cooperative (Washington DC)
    - 2.1 kW systems for $11,550 producing 2,682 kWh/year
    - Negotiated with several installers and pitted them against each other to provide the best price to each co-op member (70 members)
        - Average installed costs near $5.50/W
    - Receives federal tax credit (30%), District grant program ($6,300), sale of SRECs

        - Estimated payback is less than 3 years
    - Makes solar ownership possible and affordable
        - BUT, doesn't help people living in shady areas
    - *STRENGTHS:* solar ITC, district grant, SRECs, good payback return
    - *WEAKNESSES:* doesn't help shady areas

- Colorado "Community Solar Garden" act (June 2010)
    - Solar gardens that must be owned by at least 10 people and produce no more than 2 MW, rooftop or mounded on the ground
    - Subscribers must purchase at least 1 kW, no more than 120% of electricity consumption
- Washington Community Solar Enabling Act (2010)
    - Community solar project limitations:
        - 75 kW or less
        - On government property or utility property (if built by utility)
    - Community solar projects get 2x the incentive of other PV systems ($0.30/kWh rather than $0.15/kWh)

- Ideas for community solar
    - Feed-in tariff
        - Long-term contract, fixed payment based off of project cost (solar and tidal projects given higher $/kWh than wind projects because they are more expensive currently)
    - Change federal tax credits to cash grants
    - Allow tax incentive to pass through a third-party
        - Let the tax credit be accessible to individuals purchasing power through municipalities or other non-tax groups that run solar projects
    - Ontario has payment system that gives $0.80/kWh produced on rooftops and $0.58/kWh produced on ground systems

Pennsylvania Department of Environmental Protection 2016

- Keystone Solar Project- 2012
    - 6 MW in Lancaster County, PA for $17.5 million
    - 20,000 290 W modules
    - First year output projection=750,000 kWh
        - Actual output= >8.44 million kWh (>11x prediction)
    - 25 year PPA with Exelon Generation Company
    - Funds raised from grants (Pennsylvania Economic Development Authority gave $1 million, also from PA Sustainable Energy Fund)
        - SRECs sales also contributed to the project financing
    - *STRENGTHS:* grants, SRECs, large production
    - *WEAKNESSES:* otherwise expensive project

National Rural Electric Cooperative Association 2015

- Southern Maryland Electric Cooperative (SMECO)
    - Powers ⅔ residential, ⅓ commercial
    - Constructed by Sun Edison for $20 million ($14 million due to grant)
        - Received $6 million grant from American Recovery and Reinvestment Act (2009)-- Section 1603
    - $2.55/W
    - Subsidiary created→ SMECO Solar
    - 5.5 MW PV array completed in December 2012
        - 33 acres in Hughesville, MD
        - Capacity factory= 18.5%
        - 23,716 panels (280 W) using 11 (500 kW) inverters
    - *STRENGTHS:* received a grant, SRECs
    - *WEAKNESSES:* only cover SMECO's solar requirement for a few years so another facility is needed (Rockfist Solar project)

Orlando Utilities Commission 2013; Orlando Utilities Commission 2016

- Community Solar Farm w/ OUC-- 2013 at Gardenia facility
    - 400 kW (1,312 panels)
    - 39 customers (sold out in 6 days)
        - $0.13/kWh= ~$14.56/month per block (can subscribe up to 15-1kW blocks)- fixed cost for subscription length (up to 25 years)
        - 55% of OUC customers live in multi-family homes
    - **Spear 2013**
        - PPA w/ ESA Renewables LLC→ OUC buys for $0.18 kWh
        - Financed by ESA Renewables-- about $1.2 million
    - *STRENGTHS:* fixed rate for course of 25 years, renters have access to project, good location (parking lot), federal ITC, lot of demand for solar (plans for new 13 MW solar farm)
    - *WEAKNESSES:* solar rate ($0.13/kWh) > retail rate ($0.105/kWh), expensive installation costs

Molle 2016

- TransActive Grid- by LO3 Energy and ConsenSys
    - Runs in Brooklyn between 15 households (2 energy producers, 13 potential buyers)
    - Managed and secured by blockchain
        - Blockchain offers low cost contracting for buying/selling of energy credits
    - Uses smart meters to offer real time data
    - No third party or middleman (electrical utilities not involved in buying/selling)
        - Directly contributes to community rather than a business
        - Peer-to-peer network

Brooklyn Microgrid 2016

- Brooklyn Microgrid- by LO3 Energy

- Eric Frumin (one of the households with panels installed)
    - 20 panels
    - $43,000 in total (about $30,000 provided through incentives)
    - 7 year ROI
    - 26,942 lbs of CO2 saved

Mendelsohn et al. 2012

- CSP (concentrated solar power)-- different than PV systems
    - CSP tower, trough, parabolic dish, linear Fresnel reflector
    - Require direct sunlight to operate whereas PV can operate under indirect radiation (use axis trackers to follow sun)
- PV systems consist of either:
    - c-Si (crystalline silicon)
        - Monocrystalline (more expensive/efficient) or polycrystalline cells
        - 80-90% of PV systems use c-Si
        - c-Si wafers (energy intensive process of slicing silicon)
        - General efficiency rate= 14-20%
    - Thin-film solar modules
        - CdTe (cadmium telluride), CIGS (copper indium gallium selenide), and a-Si (amorphous silicon)
        - Generally cheaper cost but lower efficiency rate (lower solar panel efficiency ratio→ ratio of power produced by module to power of sunlight hitting module)
        - More efficient on cloudy days (and dawn/dusk) than c-Si models
        - General efficiency rate= ~11%
    - Alternate to PV→ CPV
        - High efficiency CPV systems average general efficiency rate= ~30% but very expensive

Different types of solar energy technologies: PV systems, CSP systems, solar water heating systems, solar walls (air ventilation)

Community solar with larger capacities offer economies of scale (more economically attractive to customers with different purchasing powers/income)

<u>Pennsylvania Renewable Energy Programs and Policies:</u>

- **Pennsylvania Department of Environmental Protection 2014**
- Pennsylvania Sunshine Program
    - May 2009- November 2013
    - $113 million worth of rebates generated $564.6 million in renewable energy investment
    - Covered residential systems up to 10 kW
    - 200 MW of PV installed by end of 2013 (in 2008, PA had < 3 MW)

            - 98 MW as a direct result from program
        - Rebates up to 35% of total cost
            - 91.8% of rebates for PV systems (other 8.2% for solar hot water systems)
        - Beginning of the program→ installed costs= > $7/W
        - End of the program→ installed costs= < $4/W
        - 7,035 PV systems installed (6,172 residential, 863 commercial)
        - Authorized by Alternative Energy Investment Act (below)
        - 142 million kWh/year generated
        - Currently not in effect but reinvestment is supported by Governor Wolf

- **Pennsylvania Department of Environmental Protection [2015]()**
    - PA Sunshine Program
    - GHG emissions displaced ~84,000 tons of CO_2 (~8.4 million gallons of gas consumed)
    - ~525,400 lbs of sulfur oxides and 167,418 lbs of nitrogen oxides displaced
    - Governor Tom Wolf wants to reinvest in PA Sunshine Solar Program and increase Alternative Energy Portfolio Standard
        - AEPS: Tier 1= 8% (0.5% PV) by 2021
            - Have been bills proposing to increase to 15% (1.5% PV) by 2023
        - National Renewable Energy Laboratory reports estimates 20 GW in potential rooftop solar PV in PA
        - Wants to put funding in Sunshine rebate program and create feed-in tariff

- **Pennsylvania Department of Conservation and Natural Resources [2015]()**
- Governor Wolf's 2015-16 budget includes:
    - $50 million to reinvest in PA Sunshine Solar Program
    - $50 million for grants for projects improving energy efficiency for small businesses, schools, non-profits

- **Database of State Incentives for Renewables & Efficiency [2016]()**
- Alternative Energy Portfolio Standard- November 30, 2004
    - Pennsylvania requires all electric supplying companies to supply at least 18% of its electricity from alternative energy sources by 2020 (and minimum 0.5% from PV systems)-- currently at 11%
    - 8% from Tier 1, 10% from Tier 2 technology
    - **Pennsylvania Public Utility Commission [2013]()**
        - AEPS results as of May 31, 2013
            - 6,869 solar facilities w/ 196 MW capacity in PA
            - 2,063 solar facilities w/ 112 MW capacity outside PA

            - Other states have amended the standards to make the requirement for both Tier 1 energy and PV (bills in PA congress to make standard higher but have not been passed)
        - Currently in effect

- **PA Solar 2016**
- Alternative Energy Investment Act- signed July 9th, 2008
    - $650 million for renewable energy and energy conservation
        - $180 million for solar ($100 million for household/small business installation, $80 million for commercial projects)-- up to 35% cost
    - Bill passed in PA congress in spring 2016 taking $12 million out of Alternative Energy Investment Act fund and using it for natural gas infrastructure projects

- **Department of Community and Economic Development 2016**
- Alternative and Clean Energy Program (ACE)
    - $165 million budget
    - Run jointly by Department of Community and Economic Development (DCED) and the Department of Environmental Protection (DEP)
    - loan= no more than $5 million or 50% of total cost
    - grant= no more than $2 million or 30% of total cost
    - Applies for businesses, development organizations, municipalities, schools
    - Requirement matching investment of $1 for every $1 of funds
    - ***Solar projects not included in this, but if they are part of a bigger project then they can be included
    - Funded by the Commonwealth Financing Authority
        - Funds from Alternative Energy Investment Act
    - Not currently in effect (applications accepted until April 2016)

- **Database of State Incentives for Renewables & Efficiency 2016**
- Net metering- 2006
    - PA law that investor-owned utilities must provide net metering to customers
            - Residential PPA capped at 50kW
            - Non-residential PPA capped at 3MW
    - Community net metering
        - Community shares the credit for single-entity energy production
        - allowed in Pennsylvania (within 2 mile radius)
    - aggregate net metering
        - Accumulation of net metering for multiple accounts within 2 mile radius owned by customer
        - Allowed in Pennsylvania
    - Virtual net metering

        - Net metering for single property with multiple accounts/tenants
            - Ex: condo, multi family home, etc.
        - Allowed in Pennsylvania

- **Department of Community and Economic Development 2016**
- Solar Energy Program (SEP)
    - Run jointly by Department of Community and Economic Development (DCED) and the Department of Environmental Protection (DEP)
    - loan= no more than $5 million or $2.25/W
    - grant= no more than $1 million or $2.25/W
    - Applies for businesses, development organizations, municipalities, schools
    - Funded by the Commonwealth Financing Authority
    - Currently not in effect (modifications in place for guidelines, but should resume soon)

- **KeystoneHELP 2016**
- KeystoneHELP
    - For energy efficiency improvements
    - Combined household income <$150,000
    - Loan up to $20,000 with fixed monthly payments (low interest loans)
    - Funded by Pennsylvania Treasury, PennVEST
    - Currently in effect
    - **Brown and Conover 2009**
    - Originally launched in 2006 with $20 million allocation
        - Award winning residential financing program
        - 8.99% interest rate for first 3 years
            - More than 3,000 loans and close to $20 million loaned by 2009

- **Pennsylvania General Assembly 2007**
- House Bill No.14 Special Session 1 2007-08
    - up to $10,000,000 annually to the Energy Development Authority for advanced energy projects
    - up to $5,000,000 annually to the Department of Community and Economic Development for brownfields remediation
    - up to $11,000,000 to the Residential Solar Power Assistance and Education Fund (this fund now established)
    - Currently in effect

- **Pennsylvania Housing Finance Agency 2016**
- Homeowners Energy Efficiency Loan Program (HEELP)
    - Loans between $1,000-$10,000 for energy efficient repairs at fixed rate of 1% interest

        - From Alternative Energy Investment Act
        - Currently in effect

Schneider and Sargent 2014

- Pennsylvania solar capacity grew by 39 MW in 2013 (16% increase)
    - From 196 MW to 235 MW
- PV produces 96% less pollution than coal-fired plants
    - And 91% less pollution than natural gas-fired plants
- Cost of solar energy systems has dropped by 60% since 2011

Federal Renewable Energy Programs and Policies:

- Solar Investment Tax Credit (ITC):
    - one time 30% tax credit on installation costs (for taxpayers--individual and community solar are applicable)
    - Section 25D of Internal Revenue Code
- **Database of State Incentives for Renewables and Efficiency 2015**
    - Created by Energy Policy Act of 2005
        - Original $800 million allocated
    - Tax Relief and Health Care Act of 2006-- additional $400 million for 2008
    - The Energy Improvement and Extension Act of 2008-- $800 million allocated
    - ARRA of 2009-- additional $1.6 million
- **Database of State Incentives for Renewables and Efficiency 2015**
    - Energy-efficient mortgages
        - Finance your property plus set amount for energy improvements
        - The maximum amount of the portion of the EEM for energy improvements is the lesser of 5% of:
            - the value of the property, or
            - 115% of the median area price of a single family dwelling, or
            - 150% of the conforming Freddie Mac limit.
- **Steinberg et al. 2012**
- US Treasury Section 1603 (part of ARRA of 2009)
    - As of November 10, 2011 (using 2009-dollars)
        - PV projects (96% of funded projects, 13% of funds, 5% of generation capacity, $3.3 billion in investment)
        - Large wind projects (<1% of funded projects, 79% of funds, 90% of generation capacity, $27.3 billion in investment)
        - Estimated total generation capacity= 14.4 GW
        - Construction period jobs
            - 150,000-220,000 job years→ full time employment for one person for full year
                - wind= 130,000-190,000 total jobs
                - PV= 24,000-28,000 total jobs

            - Total economic output estimate=$26-$44 billion
        - Operations and maintenance jobs
            - support 5,100-5,500 jobs per year for life of system
                - wind= 4,500-4,900 total jobs
                - PV= 610-630 total jobs
            - Total economic output estimate= $1.7-$1.8 billion
    - **Department of Treasury 2016**
    - As of April 30, 2016
        - Over 104,000 projects funded
        - $24.9 billion of 1603 funds
        - Total investment= $90.1 billion
        - Total generation capacity= 33.3 GW
- **Database of State Incentives for Renewables and Efficiency 2016**
    - Modified Accelerated Cost-Recovery System (MACRS)- Tax Reform Act of 1986
        - Encourages private investment and speeds up ROI
        - Equipt installed:
            - Before January 1, 2018 can qualify for 50% bonus depreciation
            - During 2018 can qualify for 40% bonus depreciation
            - During 2019 can qualify for 30% bonus depreciation
- **Database of State Incentives for Renewables and Efficiency 2016**
    - Low Income Home Energy Assistance Program (LIHEAP)
        - Department of Health and Human Services
        - Established in 1981 as part of Omnibus Budget Reconciliation Act
        - For tribal governments and low income households
        - Maximum income level= 150% of poverty line

Key terms

- Capacity factor: ratio of actual output to potential output if able to operate at full power
- Net metering: credited for surplus electricity generated
- Feed-in tariff: contract with electric company to supply electricity to grid (sell your electricity produced to electric company for them to sell/distribute)
- Pre-paid green pricing: paying a premium for energy (initial payment > return)
- Bottom-up approach: piecing together low-performing (poorer) areas and working to make them more complex (developed)
- Cross-subsidization: wealthier customers pay more to offset subsidy to poorer customer
- **Database of State Incentives for Renewables and Efficiency 2015**
    - Solar renewable energy credits (SRECs)/Solar alternative energy credits (SAECs): proof of 1 MWh generated by PV facility
    - Electricity suppliers must purchase these energy credits to meet obligations or pay solar alternative compliance payment (SACP-- priced at 200% market value of SAECs)
    - PA is one of two states that allows systems to register outside of the state

        - Creates an oversupplied market→ SREC prices have fallen
        - **Pennsylvania Public Utilities Commission 2016**
            - SREC weighted average price in 2009/2010= $325.00
            - SREC weighted average price in 2014/2015= $78.62
                - Continuing to decrease in 2016
- JEDI Model (Jobs and Economic Development Impact)

U.S. Energy Information Administration 2015

- ~60% of PA covered by the Marcellus Shale (largest natural gas field in US)
    - Natural gas output exceeded 4.7 trillion cubic feet (2nd most in US behind Texas)
- One of the nation's top 5 largest coal producers *and* one of top consumers
- One of the nation's top 3 largest generators of electricity
- Second in nuclear generating capacity behind Illinois

Solar Energy Industries Association 2016

- Close to 500 solar companies in PA
- 258 MW in total of installed solar capacity (15th in nation)
- 2015- $32 million invested in solar installation (21% increase from 2014)
- Installed PV systems prices dropped by 12% since 2015, 66% since 2010

Appendix B- Governmental Policies and Programs

Policy/Program	***State/Federal***	***Producer***	***Donor(s)***	***Date of Establishment***	***Current status***
Sunshine Program	State	Pennsylvania Department of Environmental Protection	Alternative Energy Investment Act ($100 million), American Recovery and Reinvestment Act (~$9 million), Clean Air funds (~$3 million), Pennsylvania Public Utilities Commission (~$1 million), US Department of Energy (~$115,000)	May 2009	ended in November 2013
Alternative Energy Portfolio Standard	State	Pennsylvania General Assembly	n/a	November 2004	ongoing
Alternative Energy Investment Act	State	Pennsylvania General Assembly	State	July 2008	ongoing
Alternative and Clean Energy Program (ACE)	State	Department of Economic and Community Development & the Department of Environmental Protection	Commonwealth Financing Authority (via Alternative Energy Investment Act)	May 2009	applications accepted from February 2016 to April 2016
Net Metering	State	Pennsylvania Public Utilities Commission	electrical utilities	2006	ongoing
Solar Energy Program	State	Department of Economic and Community Development & the Department of Environmental Protection	Commonwealth Financing Authority (via Alternative Energy Investment Act)		applications not currently accepted (while revisions being made)
Keystone Home Energy Loan Program (KeystoneHELP)	State	The Pennsylvania Treasury	The Pennsylvania Treasury & Pennsylvania Infrastructure Investment Authority (PennVEST)	launched in 2006, funds exhausted in 2014, relaunched in 2016	ongoing
House Bill No.14 Special Session 1 2007-08	State	Pennsylvania General Assembly	the Department of Environmental Protection via the state	September 2007	ongoing
Homeowners Energy Efficiency Loan Program (HEELP)	State	Pennsylvania Housing Finance Agency	Alternative Energy Investment Act	July 2008	ongoing
Solar Investment Tax Credit	Federal	U.S. Congress (Energy Policy Act)	Internal Revenue Service	2005	ongoing
Clean Renewable Energy Bonds (CREBs)	Federal	U.S. Congress (Energy Policy Act)	Department of Treasury	2005	ongoing
Energy-Efficient Mortgages	Federal	Federal Housing Administration	Federal Housing Administration (part of Department of Housing & Urban Development)		ongoing
1603 Treasury Program	Federal	U.S. Congress (American Recovery and Reinvestment Act)	Department of Treasury	2009	ongoing
Modified Accelerated Cost-Recovery System (MACRS)	Federal	U.S. Congress (Tax Reform Act)	Internal Revenue Service	1986	ongoing
Low Income Home Energy Assistance Program (LIHEAP)	Federal	U.S. Congress (Omnibus Budget Reconciliation Act)	Department of Health & Human Services	1981	ongoing

Policy/Program	***Target beneficiaries/audience***	***Special regulations/restrictions***	***Incentive Type***	***Impact***
Sunshine Program	households, commericial	residential systems up to 10 kW	$113 million rebates (up to 35% of system)	$564.6 million in renewable energy investment; over 200 MW by 2013 (98 MW direct result); installation price dropped from $7/W to $4/W by end); 142 million kWh/year; over 7,000 systems, thousands of chemical emissions displaced
Alternative Energy Portfolio Standard	electric suppliers	electric suppliers must supply at least 18% of electricity from alternative energy sources, 8% from Tier 1 (0.5% PV), 10% Tier 2	pay solar alternative compliance payments (SACPs) set at 200% market value of solar alternative energy credits (SAECs) if fail to meet obligations	7,000 solar systems in state with capacity of 196 MW; 2,000 solar systems outside of state with capacity of 112 MW (as of May 2013)
Alternative Energy Investment Act	households, small business, commericial		$650 million for renewable energy projects and energy conservation, of that $180 million for solar ($100 million for households/small businesses, $80 million for commercial)- up to 35% cost	established the Alternative Energy Development Program, the Consumer Energy Program, the Home Energy Efficiency Loan Program (HEELP), the Home Energy Efficiency Loan Fund and the Alternative Energy Production Tax Credit Program; funded the PA Sunshine Program; $12 million removed from this fund for natural gas infrastructure projects in spring 2016
Alternative and Clean Energy Program (ACE)	commercial, developmental organizations, municipalites, schools, nonprofits	required matching investment of $1 for every $1 of funds; solar power projects not permitted unless part of a bigger project	$165 million budget; loans- no more than $5 million or 50% of cost; grants- no more than $2 million or 30% of cost	
Net Metering	everyone	system capacity limit (50 kW for residential, 3 MW for nonresidential, 5 MW for micro-grid/emergency systems)	excess energy produced credit at full retail rate ($/kWh)	
Solar Energy Program	commercial, developmental organizations, municipalites, schools, nonprofits	required matching investment of $1 for every $1 of funds	loans- no more than $5 million or $2.25/W; grants- no more than $1 million or $2.25/W	
Keystone Home Energy Loan Program (KeystoneHELP)	households	eligible if combined household income is less than $150,000	loans up to $20,000	$100 million in energy efficient projects to over 14,000 Pennsylvanians
House Bill No.14 Special Session 1 2007-08	provided to the DEP to distribute to state agencies		$230 million to DEP; funds to the Energy Development Authority for advanced energy projects (up to $10,000,000 annually), to the Department of Community and Economic Development for brownfields remediation (up to $5,000,000 annually); to the Residential Solar Power Assistance and Education Fund (up to $11,000,000)	established the Residential Solar Power Assistance and Education Fund
Homeowners Energy Efficiency Loan Program (HEELP)	households	income limits (ex: $38,350/year for one person, $43,580/year for two persons, etc.); no more than 150% of area median income	loans up to $10,000	
Solar Investment Tax Credit	households and communities	applies to taxpayers only	one time credit for 30% of installation cost	job creation, more affordable, lower prices
Clean Renewable Energy Bonds (CREBs)	cooperatives, municipalities, non-profits	applies to nontaxpayers only	$1.2 billion reserved for the first three years; additional $2.4 billion reserved in 2009	funding source for nontaxpayers
Energy-Efficient Mortgages	mortgage payers		the lesser of 5% of a) the value of the property, b) 115% of the median area price of a single family dwelling, or c) 150% of the conforming Freddie Mac limit	
1603 Treasury Program	households, small businesses	not applicable to non-profits, municipalities	in lieu of solar ITC, also worth 30% of installation cost; $24.9 billion worth of funds	cash option for customers (rather than credit); over 104,000 projects funded; $90.1 billion of investment; 33.3 GW generation capacity, hundred of thousands jobs created
Modified Accelerated Cost-Recovery System (MACRS)	businesses		50% bonus depreciation for projects before 2018, 40% bonus depreciation for projects during 2018, 30% bonus depreciation for projects during 2019	encourages private investment, speeds up return on investment
Low Income Home Energy Assistance Program (LIHEAP)	tribal government, low income households	maximum income level is 150% of poverty line	grants for home energy bills, energy crises, weatherization/minor home repairs	financing for low income residents

Appendix C- Project Comparison

Brazil

Project Name/Organization	*Source*
Companhia de Electricidade do Estado da Bahia (COELBA)-- part of Luza Para Todos	Zerriffi 2011
compartia Energética de Minas Gerais (CEMIG)-- part of PRODEEM	Zerriffi 2011
National Programme for Energy Development of States and Municipalities (PRODEEM)	Zerriffi 2011
Institute for the Development of Alternative Energies and Self Sustainability (IDEAAS) w/ STA	Zerriffi 2011

Cambodia

Project Name/Organization	*Source*
Khmer Solar	Zerriffi 2011
Japanese PV/Hydro	Zerriffi 2011

China

Project Name/Organization	*Source*
Wind/Solar Hybrid	Zerriffi 2011
Township Electrification Program (TEP)-- part of the Brightness Program	Zerriffi 2011
China Renewable Energy Development Project (REDP)	Zerriffi 2011

India

Project Name/Organization	*Source*
Minda NextGenTech Ltd	Hinds and Abdullah 2012
Gram Power	Hinds and Abdullah 2012
Scatec Solar	Hinds and Abdullah 2012

Dominican Republic

Project Name/Organization	*Source*
Solar Based Rural Electrification Concept (SO-BASEC)	Enersol 2009; Covell 1990

Bangladesh

Project Name/Organization	*Source*
Grameen Shakti	Komatsu et al. 2011; Grameen Shakti 2016

Denmark

Project Name/Organization	*Source*
Samso Island	Nielsen and Jørgensen 2015; Kuang et al. 2016; Godoy and Tierramerica 2009; McLaren 2014; PlanEnergi & Samsø Energy Academy 2007

United States

Project Name/Organization	*Source*
Clean Energy Collective (CEC) w/ Holy Cross Energy	Farrell 2010
Sol Partners w/ United Power	Farrell 2010
Florida Keys Electric Cooperative (FKEC) Simple Solar Program	Farrell 2010
University Park Community Solar, LLC	Farrell 2010
Greenhouse Solar Project w/ Appalachian Institute for Renewable Energy	Farrell 2010
Solar Pioneer II	Farrell 2010
SunSmart w/ The City of St. George Energy Services Department and Dixie Escalante Electric	Farrell 2010
Ellensburg Community Solar Project	Farrell 2010; Solar Washington 2014
Solar for Sakai w/ Community Energy Solutions	Farrell 2010; Bainbridge Island Review 2008
Mt. Pleasant Solar Cooperative	Farrell 2010
Keystone Solar Project w/ Community Energy	Pennsylvania Department of Environmental Protection 2016
Southern Maryland Electric Cooperative (SMECO)	National Rural Electric Cooperative Association 2015
Orlando Utilities Commission's Community Solar Farm w/ ESA Renewables LLC	Orlando Utilities Commission 2013; Orlando Utilities Commission 2016; Spear 2013
TransActive Grid and Brooklyn Microgrid w/ LO3 Energy and ConsenSys	Molle 2016; Brooklyn Microgrid 2016

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1960	Bahia	individual households (SHSs)	13 kWh/month	36,000 expected
1996	Minas Gerais	individual households (SHSs), community structures, water pumping	50, 100W	450 household, 115 communal (while 4,700 were expected)
1994	nationwide	community structures, water pumping, public lighting (all PV)	5,209 kW (total)	5,914 communal buildings, 2,449 water pumping, 379 public lighting
1997	southern China	individual (wealthy) households (SHSs)	60, 90, 120 W	less than 300

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1997	Phnom Penh, Battambang	individual (wealthy) households (SHSs), NGO offices/projects (SHSs)	85 W	200 (in 2005)
2005	single community	households via microgrid	100 kW (total)	PV/hydro micro-grid, 5 satellite PV battery charging stations (410 households)

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1996	Inner Mongolian Autonomous Region	individual (wealthy) households (wind/PV hybrid systems)	400-500 W	8,400 PV/wind hybrids
2002	nationwide	households & community structures via mini-grid	220 MW (total)	small hydropower (378 villages), PV (666 villages), hybrid (17 villages)
1999	western China	individual households (SHSs)	around 20 W	~50,000/year

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
2012	Indira Nagar, Rajasthan	households via microgrid	240 W	one power plant
2012	Rajasthan	households via smart grid	10 kWp	one microgrid
2011	Uttar Pradesh, Madhya Pradesh, Jharkhand, and Jammu and Kashmir	community solar farm as microgrid or charging station	4-25 kWp (290 kWP total)	power plants set up as microgrids and charging stations for 28 villages (1,300 families)

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1988	Puerto Plata and Bella Vista, spread nationwide	individual households & community structures (SHSs)	48 Wp	over 1,000 nationwide (by 1990)

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1996	rural Bangladesh	individual households (SHSs)	40, 50, 65, 85, 120, 130 Wp	over 1.6 million (by 2015)

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
1997	Samso Island	onshore/offshore wind turbines, individual household (SHSs)	1 MW (onshore) and 2.3 MW (offshore) turbines	21 wind turbines (11 onshore, 10 offshore), 4 generators (powered by hay combustion)

Year Established (Project)	*Location*	*Installation Plan*	*System Size*	*Systems Installed*
2010	El Jebel, Colorado	community solar farm	77.7 kW (230 W panel)	one solar farm (340 panels)
2010	Brighton, Colorado	cooperative solar farm	10 kW (210 W panel)	one solar farm
2008	Marathon, Florida	cooperative solar array	96.6 kW (175 W panel)	one solar array (552 panels)
2010	College Park, Maryland	community solar array (attached to church)	22 kW	one solar array (99 panels)
2009	Boone, North Carolina	community solar array (attached to building)	2.4 kW	one solar array
2012	Ashland, Oregon	community solar array (on top of covered parking lot)	64 kW (175 W panel)	one solar array (363 panels)
2009	St. George, Utah	community solar farm	100 kW (500 W panel)	one solar farm
2006	Ellensburg, Washington	community solar array	111 kW combined (multiple phases)	one solar array (192 polycrystalline modules, 720 thin-film modules)
2009	Bainbridge Island, Washington	solar array (attached to school)	5.1 kW	one solar array (30 panels)
2006	Washington, DC	individual households (via bargaining cooperative)	2.1 kW	close to 100
2012	East Drumor, Pennsylvania	community solar farm	6 MW (290 W panel)	one solar farm (20,000 modules)
2012	Hughesville, Maryland	community solar array	5.5 MW (280 W panel)	one solar array (23,716 panels)
2013	Orlando, Florida	community solar farm (on top of covered parking lot)	400 kW	one solar farm (1,312 panels)
2016	Brooklyn, New York	TransActive Element grid meters connected to microgrid		one meter attached to each producer, distributes power to neighbors

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
X	Luz Para Todos funds	X	X
			X
			X
X			

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	Japanese government		X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	30% subsidy per system	X	
	large government funds		X
	raised from $1.5/W to $2/W		X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
		X	X
	30% subsidy per system	X	X
	from MNRE and the Norad (The Norwegian Agency for Development Cooperation)	X	X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	> 17,000 pesos from US AID	X	X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	micro-credit plan with financial agencies		X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	funds from the Danish Energy Authority	X	X

Strengths

Cross-Subsidization	*Incentives and Funds*	*Geographic Location/Weather*	*Ideology (cause/intention)*
	30% ITC, utility rebate & RECs (totaling $1.5/W)	X	
	$50,000 from governor		
	CREBs		
	30% ITC, accelerated depreciation (MACRS)	X	
	30% ITC, 35% state tax credit	X	
	CREBs, Oregon New Rules Project Business Energy Tax Credit Pass-Through (35% credit)	X	
	25% state tax credit (up to $2,000)		
	from private investors (individuals and organizations), $0.30/kWh state incentive for community solar		
	$30,000 from individual/organizations, $20,000 from Puget Sound Energy grant	X	
	30% ITC, $6,300 district grant		
	$1 million from PEDA		X
	$6 million from American Recovery and Reinvestment Act (1603 Treasury Program)		X
	30% ITC, financed by ESA Renewables LLC	X	X
	NYSERDA installation incentives, federal incentives, ~80-90% installation costs covered		X

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
X					
X					
	X				
	X				reliable

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
		X			1-year warranty, more capacity for those who can afford, reliable
X					

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
					short-term needs covered
X					

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
X			X	X	
X	X	X		X	smart pre-paid meter system, demand-driven model
			X	X	bottom-up approach

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
X		X	X	X	not connected to national grid (prone to blackouts)

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
X	X		X	X	decentralized, SHS powered Polli Phone

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
	X	X	X	X	net positive energy budget, diverse energy systems

Affordability	*Variability (in size/system)*	*Cost-Recovery*	*Externalities*	*Community Involvement*	*Other*
		X			owners receive more than retail production rate, PPA w/ Holy Cross
X					
X		X		X	SSA w/ church
					PPA w/ AIRE building
					owners receive more than retail production rate
		X			
				X	state production incentive ($0.15/kWh)
X		X			cooperative that helps with individual installation (access to ITC)
					very large project, PPA w/ Exelon Generation Company
					very large project, led to development of Rockfish project
X	X	X			cost is fixed over suscription length (no price increases), renters have access
	X		X	X	uses blockchain technology, no middleman, benefits community

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
X			X			
X				X		X
X	X			X		X
X						

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
		X				
X	X			X		X

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
		X				
	X			X		X
X						

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
X						
		X				

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
X	X					

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
X	X					

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*

Weaknesses

Limited Power	*Dependency on Donors*	*Affordability*	*Variability (in size)*	*Cost-Recovery*	*Green Pricing*	*Sustainability*
		X		X	X	
	X					
					X	
		X		X	X	
		X		X	X	
		X			X	
	X	X		X		
		X				
					X	
		X			X	

Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
				covered 90% of costs (expected 64%)
X	X	X		highly centralized, doesn't cover operating costs
		X		entirely financed by federal government
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
		X		50% import tariff on solar panels, most rural areas can't afford SHSs
	X	X		power only provided from 6-9 pm
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
	X		X	
				top-down approach, highly centralized, entirely financed by federal government
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
	X			cultural (approval from panchayat), advanced microgrid would be difficult to fix if harmed
				expensive in long-run, not coordinated with local government
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
				customers are dependent on micro-credit plans to cover for high up-front investment
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
			X	transportation has not been reduced (gas consumption remains constant)
Community Involvement	*Equipment/Structure*	*Target Customers*	*Weather Dependent*	*Other*
				must oblige to rules/restrictions of a private enterprise
				very small project
				donors do not get ownership (project depends on altrusitic nature of public)
				doesn't help properties in shady areas
				solar rate ($0.13/kWh) is greater than retail rate ($0.105/kWh) but is fixed rate, expensive installation costs
				buyers pay $0.07 more for kWh (~$8-14/month)

Appendix D- Survey

Community Distributed Solar

This survey is part of a project for the Bucknell Institute for Public Policy. We are gathering data to help us develop research that will further the advancement of our understanding of why households may or may not invest in solar energy, and to assess potential for community distributed solar power in central Pennsylvania. Data will remain anonymous and the survey should take no more than five to ten minutes. There will be no risk to you and this survey is completely voluntary. You may choose to stop the survey at any time. If you have any questions or comments, please contact Dr. Shaunna Barnhart at shaunna.barnhart@bucknell.edu or by phone at 570-577-1724 or Reid Harrison at rmh033@bucknell.edu or by phone at 267-885-8593. We appreciate your time and help with our project.

Demographic Information (please circle your response)

Gender	Male	Female	Other	Prefer not to answer	

Age: __________

County of Residence: ______________________________

Ownership status	Property owner	Property renter	Other ________________________________		
Type of property	Single family home	Multi family residence or duplex	Farm	Business	
Current solar power status	Panels installed on property	Panels not installed on property	Panels not installed on property, but receiving solar from other source (i.e. micro grid)	Panels not installed on property, but planning on it	Panels not installed on property, but potentially interested
Installation design	Ground-mounted or open-field array	Structurally-mounted or roof-design	Panels not installed, but prefer ground-mounted or open-field array	Panels not installed, but prefer structurally-mounted or roof-design	Not currently interested in solar panel installation

When thinking about why you installed, or would consider installing, solar panels on your property, how important are each of the following factors? (please circle your response)

Financial affordability	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important

Environmental Impacts	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Reduces greenhouse gas emissions	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Energy Independence	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Economic benefits (i.e. employment, income)	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Geography/location	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Health reasons	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Federal/State incentives	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Friends/Neighbors have solar panels installed	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
Other________________________	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important

Community Distributed Solar (please circle your response)

Community distributed solar describes the shared energy and results of a solar energy plant by members of a community, rather than individual solar home systems, which are meant for one only household. Each member pays for shares of energy, which is received from the plant via an electrical grid. Members also receive financial benefits from the excess energy produced under the process of net metering.

Familiarity with community distributed solar power	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
Level of desirability for community distributed system	Very undesirable	Undesirable	Neutral	Desirable	Very desirable
Level of desirability for individual installation of system (single solar home system)	Very undesirable	Undesirable	Neutral	Desirable	Very desirable

Personal Beliefs on Global Change (please circle your response)

How concerned are you with climate change currently?	Not at all concerned	Slightly concerned	Somewhat concerned	Moderately concerned	Extremely concerned
How important do you believe it is to achieve energy independence?	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
How important is it for you to reduce your personal energy consumption?	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
How important is it for the United States to reduce its energy consumption as a nation?	Not at all important	Slightly important	Somewhat important	Moderately important	Extremely important
I would pay more for solar energy, even if it is more expensive than typical electricity	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Thank you, we appreciate your time and support.

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