Increasing Solar Energy Choice for Low- and Moderate-Income Households in South Carolina

Spring 2020 Applied Policy Project
Prepared for the Energy Office of South Carolina

May 2020

By Laura Daniela Gonzalez
Master of Public Policy candidate

UNIVERSITY of VIRGINIA
FRANK BATTEN SCHOOL of LEADERSHIP and PUBLIC POLICY

Acknowledgments
I would like to thank Professor Raymond Scheppach and William Shobe of the Batten School of Leadership and Public Policy for their patience and assistance in this project. Thank you to the Peyton Fellowship that allowed me to know the wonderful State of South Carolina. I am grateful to Darcy Jones and Stacy Washington from the Energy Office of South Carolina for their enthusiasm and encouragement. Thank you to my family and especially my sister for her unconditional support.

Honor Statement
On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Laura Daniela Gonzalez

Disclaimer: The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author and are not necessarily endorsed by the Batten School, the University, or any other agency

ABBREVIATIONS

CEO	Colorado Energy Office
DER	Distributed Energy Resources
IOU	Investor Owned Utilities
kWh	Kilowatt Hour
LMI	Low to Moderate-Income
MW	Megawatt
NEM	Net Energy Metering
Non-LMI	Customers that do not qualify as low-to-moderate income
NREL	National Renewable Energy Laboratory
PPA	Power Purchase Agreements
PSC	South Carolina Public Service Commission

Contents

EXCECUTIVE SUMMARY

Expanding solar energy is key to reduce the detrimental effects of electricity sector emissions. Several polices have enabled and incentive widespread adoption of solar energy in the residential sector, however low-to moderate (LMI) income households have been left out. The Energy Office of South Carolina is interested in policy alternatives to increase solar energy access for LMI households in the State. Achieving both emissions reduction and reducing the energy burden of these families.

States have adopted a wide rage of polices to increase access for LMI to solar, including credit and subsidy options for rooftop solar. However, most LMI households are unable to install solar energy on-site due to inadequate rooftop, shading, lack of ownership, and lack of capital. Thus, states have promoted off-site voluntary energy programs. These are policies to enable customers to pay directly for renewable energy, and specifically solar through their electric utilities. Voluntary policies include shared solar, and green tariffs programs

The Distributed Energy Resource Act of 2014 incentivized the most important program for LMI access in the State through shared solar. However, the Energy Freedom Act enacted in May 2019, did not require Investor owned utilities to offer new shared programs and prohibited the recovery of costs associated with these programs from non-participant rate payers. Currently the State lacks a comprehensive policy to include LMI homes in the solar market

This report evaluates four options to increase solar access to lower income households.

I. Status Quo: Studies the outcomes of not adopting any policy change
II. Require Investor Owned Utilities to offer shared solar programs for residential customers and integrate an LMI carve-out. Non-low-income subscribers will cover the extra costs associated with LMI subscriptions.
III. Adopt a direct subsidy for utilities to cover the extra costs associated with LMI subscriptions.
IV. Design a rooftop solar strategy using resources form the Weatherization assistance Program and the Low-Income Home energy Assistance Program

The policy options are evaluated using four criteria, cost-effectives, political feasibility, ese of implementation, and emissions avoided. Based on this evaluation it is recommended that the Public Service Commission adopt a shared solar mandate with a low-income carve-out, where the extra-costs associated with low-income subscriptions are supported by higher income subscribers to the program. This alternative has the highest political feasibility given the limited public resources destined to renewable energy development. It also allows utilities to recover all the costs of the program through rate structures, and maintains non-participant customers neutral.

PROBLEM STATEMENT

Low-to moderate income households (LMI) in South Carolina are excluded from the solar energy market. LMI communities as well as minority groups are more likely to live near coal plans and are especially vulnerable to climate change negative effects. Nonetheless the adoption of solar energy has been concentrated in more affluent communities (Moezzi et al., 2017). Policies that aim at incentivizing voluntary adoption of solar energy have fallen short in reaching out the whole social spectrum. Some studies have found that there has been a transfer of wealth through technology incentives and solar subsidies towards higher-income households (Vaishnav et al., 2017). Sixty percent of the tax credit available for clean energy investments have gone to the top income quantiles, and only 10 percent to the bottom three income quintiles (Borenstein & Davis, 2016).

The Berkeley National Laboratory found that the median household income (MHI) of solar adopters was $100,000 in 2010 and decreased to $87,000 in 2016, compared to the MHI of all the other households in the study of $69,000 (Barbose et al., 2018). According to the Natural Resources Defense Council, low to moderate-income households and minority groups are not integrated into the solar market and will more often suffer the consequences of a changing climate (Katharine McCormick, 2015). Sates are adopting policies to overcome financial and logistic barriers of LMI customers to adopt solar energy and achieve a more equitable access.

Prices of solar energy generation have fallen dramatically over the last decade, and those with enough capital have been able to gain savings under certain conditions. However, upfront costs of solar are still restrictive for LMI households, which hinders the possibility for them to benefit from energy savings, and alleviate the burden of electricity bills in the family budget. Moreover, a significant number of households have logistic challenges to adopt rooftop solar. In South Carolina around 67% of LMI households do not have suitable rooftops, life in multifamily houses, or rent their homes, which highly restricts their capacity to install on-site solar. This report studies three policy options that aim at tackling both financial restrictions and logistic restrictions for LMI access to solar energy.

BACKGROUND

This section provides the necessary information to formulate and evaluate alternatives for South Carolina to include LMI households in the solar energy market. First, this section describes the electricity market in South Carolina, and addresses the social cost to society associated with emissions form electric generation. It also addresses the energy burden of LMI customers in the State. Then it describes voluntary renewable energy polices, in particular shared solar, before describing the current relevant legislation and development of shared solar in the State. Finally, this section discusses best practices in other states intended to integrate, otherwise marginalized LMI and minority communities to shared solar programs and on-site solar regeneration.

South Carolina Electricity sector

Actors

South Carolina has a regulated energy market. This implies that only utilities are allowed to sell energy to retail customers. The Public Service Commission (PSC) oversees the operations of the electricity sector. The PSC regulates all tariffs that Investor Own Utilities (IOU) charge to customers, as well as the rate of return that IOUs are allowed to have from invested capital (South Carolina Code of Laws § 58-27-10).

There are four types of utilities in the State:

- The State-owned utility, Santee Cooper.
- Investor Owned Utilities, which are privately owned, including Dominion Energy, Duke Energy Carolinas, Duke Energy Progress, and Lockhart Power Company.
- Electric Cooperatives, which are organized by the Central Electric Power Cooperative. They are customer-owned entities that only deliver electricity to retail customers, and obtain most of its power through long-term purchase agreements.
- Municipal Cooperatives. South Carolina has 21 municipalities that own and operate electric distribution systems and provide electrical service in their municipality. Municipal Cooperatives are self-regulated.

Generation

The electricity generation in South Carolina depends on nuclear energy (58%), natural gas (23%), coal (12%), and renewable energies (6%). Hydropower accounts for 3% of the renewable energy generation, utility scale solar and small-scale solar accounts for less than 1%, and biomass accounts for 2% of the generation (EIA 2018).

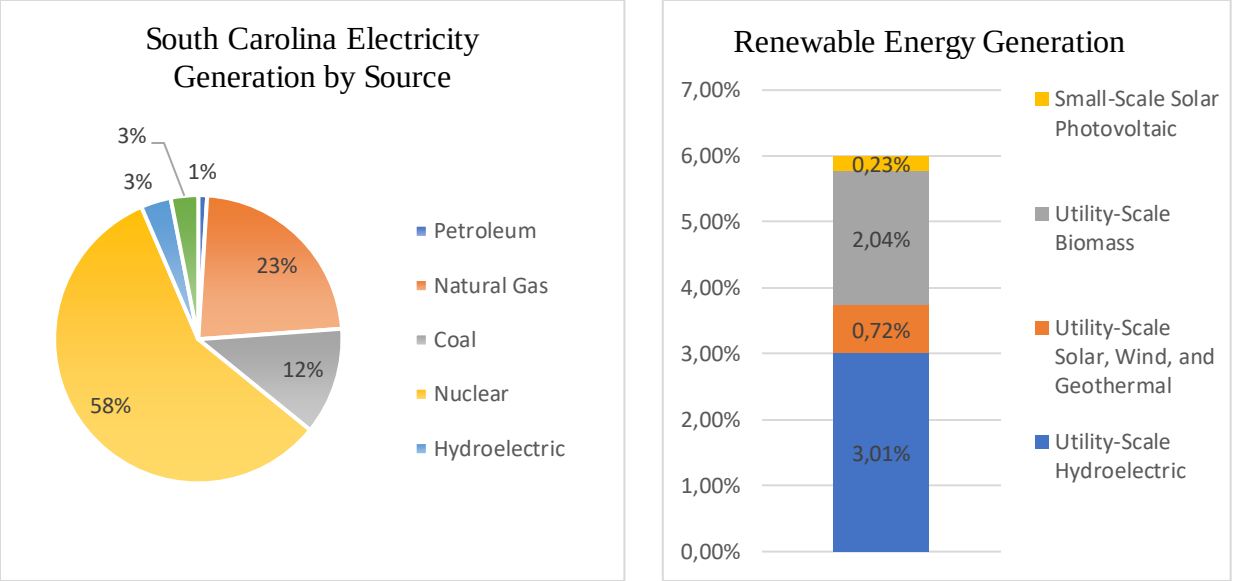


Figure 1. South Carolina Electricity Generation by Source and Renewable energy generation

The State has seven operating nuclear reactors and four nuclear power plants. Natural gas consumption for electricity generation has quadruplicated in the last decade, from 35,7 million cubic feet in 2002 to 176, 7 million in 2018 (EIA, 2019), as natural gas has replaced coal generation. Currently the State has 6 coal plants with a capacity of 5449 MW. According to the Solar Energy Industries Association (SEIA) in 2019 the solar installed capacity was 1,158.72 MW, which places the states 16th in the national ranking. The projected growth is 1,475 MW over the next 5 years which places the state 36th compared to other states.

Costs to society associated with carbon emissions from the electricity sector

Aggregate electricity generation in the State of South Carolina produces 18,070 metric tons of sulfur dioxide, 15,223 metric tons of nitrogen oxide and 28,874 thousand metric tons of carbon dioxide. To estimate the impact on human health, agricultural productivity, and property damages from increased flood risking caused by these emissions I use the social cost of carbon estimates[1]. The annual cost of the emissions produced by the electricity sector is around $779,442,676. Residential electric generation accounts for 38% of the costs. Table 1 shows the estimates of the social cost of emissions form the electricity generation in South Carolina.

[1] The EPA uses the estimated damages per ton of Carbon dioxide and Nitrogen oxide from a paper by Marten et al., (2015). I use the estimates of Shindell (2015) to calculate the impact of Sulfur dioxide emissions

Table 1. Estimates of the social cost of emissions from the electricity sector

Green House Gas	Emissions (metric tons)	Cost per metric ton $	Total annual cost to society
Sulfur dioxide	18070	20000	361,404,360
Nitrogen oxide	15223	4700	71,550,316
Carbon dioxide	28874000	12	346,488,000
Total electric system			779,442,676
Total Residential (38%)			296,188,217
Total LMI households (765,566)			124,925,557

Most of the State has warmed by one-half to one degree Fahrenheit in the last century, and the sea is rising about one to one-and-a-half inches every decade (EPA, 2016). The region's changing climate is likely to reduce crop yields, harm livestock, increase the number of hot days, cause extreme weather events and rise sea levels. The City of Charleston, for example estimates that "Tidal flooding in the 1970s averaged 2 times (…) By 2045, the City is projected to face nearly 180 tidal floods a year. The National Oceanic Atmospheric Administration estimates a sea level rise of 2 to 7 feet in Charleston over the next 100 years" (City of Charleston, 2015).

Burning coal and natural gas has a special heavy toll on human health. The State of South Carolina presents 73 deaths each year from in-state emission of fine particulate matter associated with electricity generating units (Thind et al., 2019). Moreover, coal plants generate 52 deaths, 19 asthma emergency room visits, 29 heart attacks, and 2512 work loss days each year (The Clean Air Task Force 2016).

Black Americans, Latinos and Low-income communities are the groups most affected by emissions form the electricity sector. For example, of the 26722 people that live within 3 miles of the coal plant Cross in Berkeley county 74% are black population compared with the 36% state average, and the poverty rate in the area is 51% compared to the average 16% of the State. Similarly, 50% of the 1118 people living within 3 miles of the cope coal plant are people of color. In total, there are 32,560 people that live within 3 miles of a power plant and 686,960 within a 12 miles exposure (Clean Air Task Force, 2016). Population around all coal plants in the State have similar demographic trends.

Emission levels for nuclear energy generation are comparable with some forms of renewable energy such as hydro and wind (Intergovernmental Panel on Climate Change,

2014). However, nuclear entails costly waste management programs. Currently, there are 4,880 metric tons of nuclear waste in storage at nuclear plant sites (Nuclear Energy Institute, s. f.). As of 2016, the State has contributed approximately $1.5 billion to the Federal Nuclear Waste Fund, however, there is not a permanent and safe solution for nuclear waste management.

LMI energy burden in South Carolina

Out of the 1,815,094 households in South Carolina, approximately 765,566 are low to moderate-income (LMI) households[2]. LMI households in South Carolina face high energy burdens. That is, the percentage of household income spent on energy consumption. An elevated energy burden obligates families to forego proper nutrition, education and health services to keep the electricity sypply (Drehobl & Ross, 2016). A high energy burden is between 6% and 11% of a family's income (Drehobl & Ross, 2016). The average energy burden for LMI homes in the U.S is 8.3% (LEAD Tool, s. f.).

In South Carolina, the average energy burden for LMI households is 22%, and for non-LMI is 7%. In Counties like Dillon, Barnwell, Allandale, and Clarendon, LMI households experience an energy burden above 40% (NREL Solar for all). The principal driver of the energy burden is the high consumption. While other states use natural gas and other fossil fuels for heating and cooling, most of the resident's energy needs are covered with electricity (EIA, 2018).

The average electricity price for residential customers in the State is 12.27 cents per kWh (EIA, 2018), which is close to the national average 12.5 cents. However, some electric cooperatives have elevated rates such as Haywood Electric Member Corp $19.03 cents per kWh and Clinton Combined Utility System $ 17.09 cents per kWh. Solar energy solutions make financial sense in these counties. As we describe in detail in the next sections, the cost per kWh of solar systems >500kW can be as low as $0.073 per kWh, after applying federal incentives.

[2] Very low-income families are those between 0% and 30% of the AMI; low-Income families are those between 30% to 50% of the AMI; moderate-Income families are those between 50% to 80% of the AMI; Middle Income are those between 80% to 120% of AMI; and high income are those above 120% of AMI (Sigrin & Mooney, 2018). This total is similar to the number of families at or below 200% of the Federal Poverty Line ($52,400 for a family of 4)

Energy policies for LMI households in South Carolina.

Energy efficiency is the principal intervention states adopt to address energy burden issues of LMI customers. Solar energy solutions must be implemented after energy efficiency interventions. With the right market conditions, and policy frameworks, solar can generate additional wealth for under-resourced communities (Clean Energy States Alliance, 2019). In this section I describe the energy efficiency programs and weatherization programs for LMI customers, solar programs will be addressed in the legislation section.

Federal Energy Programs

In South Carolina, the principal energy assistance programs are the Federally funded Weatherization Assistance Program (WAP), and the Low-Income Home Energy Assistance Program (LIHEAP). Local Community Action Agencies administer both programs. WAP provides home weatherization assistance to improve energy efficiency of low-income families (at or below 200% of the Federal Poverty Line), elderly people, people with disabilities, and children. In 2020 the state received $1,950,568 to weatherize 212 units. While state-level assessment data is not available, homes receiving WAP funding save on average $283 or more each year (U.S Department of Energy, 2019), the program has assisted 4,350 families.

The U.S. Department of Health and Human Services funds the LIHEAP that assists low-income families unable to pay their energy bills. It provides assistance for heating expenses, for families in crisis needing bill assistance, and weatherization improvements. In 2020 the State received $48,586,607 to allocate to these services.

State programs

The Help my Home (HMH) pilot successfully demonstrated the viability of on-bill financing for energy efficiency. The pilot provided on-bill financing for 125 families to invest in energy efficiency improvements. The average loan program was $7,684, and deferred payments in 10 years with a 2.5% interest. On-bill financing allowed customers to pay their loans through their electricity bill. Moreover, the customer obtained financing based on one year of good bill payment history rather than credit scores. Savings from whole-house energy efficiency interventions cover the monthly loan payment and left some of the savings free. For example, if the total monthly savings were $94, the monthly loan payments were $72, and the customer had $24 of net savings. The average payback period was 6.6 years, and the average annual cost reduction was $1,157, demonstrating the viability of on-bill financing for energy efficiency.

Voluntary renewable energy programs

Before describing in detail South Carolina relevant renewable energy legislation and LMI access policies, this section explains different types of solar access for residential customers in regulated markets.

The most common form for households to access renewable energy is on-site installation by homeowners and businesses. However, several households and businesses lack the physical space or site ownership to invest in on-site installation. To address this challenge, and widen adoption of renewable energy, states have adopted voluntary renewable energy programs. In these programs, regulatory stipulations require utilities to offer customers the option to pay directly for off-site renewable energy generation. Voluntary programs include green tariffs, shared solar and community choice aggregation.

Green tariffs

Utility green tariffs are intended for commercial and industrial customers to buy renewable electricity from a specific project through a special tariff rate. Utilities supply the customer with renewable power from projects either owned by the utility or contracted with independent power producers in the utility region (US EPA, 2018). Contracts can last from at least 2 years to 10, 15, or 20 years. Cost savings in these programs depend on the type of contract and the price per kWh of renewable energy.

Shared Solar and Community Solar

Shared solar programs are intended for residential customers. Utilities run shared solar programs in two frameworks:

1. Framework 1: The utility owns and maintains solar facilities and allocates the energy from the facility to specific individual subscribers.
2. Framework 2: Customers contract upfront or trough monthly payments with solar developers and receiving the bill credit from utilities, while the developer operates and maintains the system.

In both frameworks, the customer pays their regular electric bill plus the extra cost of the program, if any, to the utility or directly to the developer. The customer receives the benefits associate with the energy produced by the facility in credits against their electric bill. The credit payment depends on the solar compensation rate established by the utility. The customer will have savings if the credit exceeds the payments for the extra cost of program.

The solar facility is not always in the same county or community as the subscribers, and can often be located elsewhere in an electric utility's service territory. Some states have implemented

policies to locate the solar installation near the customers it serves, or in disadvantaged communities. These policies, help to achieve social development goals, create local jobs, or decrease transmission costs. If the program has a location requirement, it is called community solar. In this report, I use community and shared solar interchangeable.

Share solar programs can be distributed energy programs or the program can allocate capacity to customers from utility- scale centralized solar projects. Distributed energy resources (DER) are small to medium size projects between 20 kW to 20 MW, spread through the transmission and distribution lines, close to the final customer. Currently, there is a debate around the benefits and costs of distributed renewable energy, for utilities and consumers (Flores-Espino, 2015; Orrell et al., 2018) Some general benefits considered by states include avoided carbon emissions, avoided electricity losses from the points of generation to the points of delivery, and avoided generation capacity cost. (Settlement Agreement on Net Metering, 2015). Another key benefit from distributed solar is resilience, however, systems must be appropriately designed, which can increase its costs (Sherry Stou et al., 2018)

The major advantage of shared solar is that it removes individual household assessments, installations, and equipment; Shared solar is cheaper due to economies of scale and the use of optimal radiance locations. Shared solar projects can also reduce costs in brownfield locations and take advantage of the Investment Tax Credit and the Modified Accelerated Cost Recovery System incentives. Smaller on-site projects might have more administrative costs than benefits trying to take advantage of these incentives (Coleman et al., 2017; Wanderscheid et al., 2010).

Relevant energy Legislation

Sates have widely adopted policies to enable both on-site and off-site adoption of solar energy by households. The enabling legislative framework in South Carolina include the Federal Public Utilities Regulatory Act 1987 (PURPA), The Federal Energy Policy Act (EPACT 2005) the State Distributed Energy Resource Act (236-2014), and the recent state Energy Freedom Act (62-2019).

PURPA is a federal landmark legislation that required electric utilities to offer to purchase electric energy from qualifying facilities, that are renewable generation facilities of less than 80 MW capacity, at avoided cost rates. Avoided cost is the rate that approximates what it would cost the utility to generate the same amount of electricity. EPACT introduced amendments to PURPA including the requirement for utilities to make available upon request net metering for qualifying facilities. These enabling legislation was crucial for independent power producers and households to be able to connect their systems to the gird and receive compensation for the energy production.

The Distributed Energy Resource Program Act

This act implemented key dispositions to encourage distributed energy resources (DER) in the State. The law introduced Net Energy Metering (NEM) regulations allowing DER to receive credit for the energy these facilities supply to the grid. It also established the requirement for utilities to install a solar nameplate generation capacity equal to at least 2 percent of the previous five-year average of the electrical retail peak demand by 2021. The program specifies that 1 percent of capacity should come from facilities 1 MW-10MW, the other 1 percent should come from facilities <1MW, and a quarter of this 1 percent should come from facilities <20 kW.

To achieve the 2 percent goal, the act established two incentives for utilities. The first was the recovery of incremental costs associated with these facilities. The second was a DER NEM incentive. Under the DER NEM the incentive, utilities compensate DER for the energy 1:1 at the retail level, which is higher than the avoided costs for the utility. Utilities can recover the difference between the retail level and their avoided costs through the fuel clause from non-participant ratepayers.

Ratepayers funded both incentives through charges in their electric bills. The incremental costs as a fixed charge that cannot surpass $12/year for residential customers, $120/year for commercial, and $1,200/year for industrial customers. The DER NEM incentive is recovered as a charge in the fuel clause of each electric bill in a per kWh basis.

As part of a settlement agreement with the PSC utilities agreed to include within their programs share solar offerings. They also agreed to reserve part of the offering for LMI customers. The tree principal IOU developed 20 MW of share solar, and reserve 1.8 MW for LMI customers, benefiting 566 LMI households.

The Distribute Energy Resource program of 2014 had a crucial impact in the State, incentivizing households, business and utilities to install solar energy capacity. In 2014 for example there were less than 5MW of residential installations and by 2017 there were almost 80MW of residential installations as shown in Figure 2. However, the residential installations concentrated in higher income sectors as shown in Figure 3

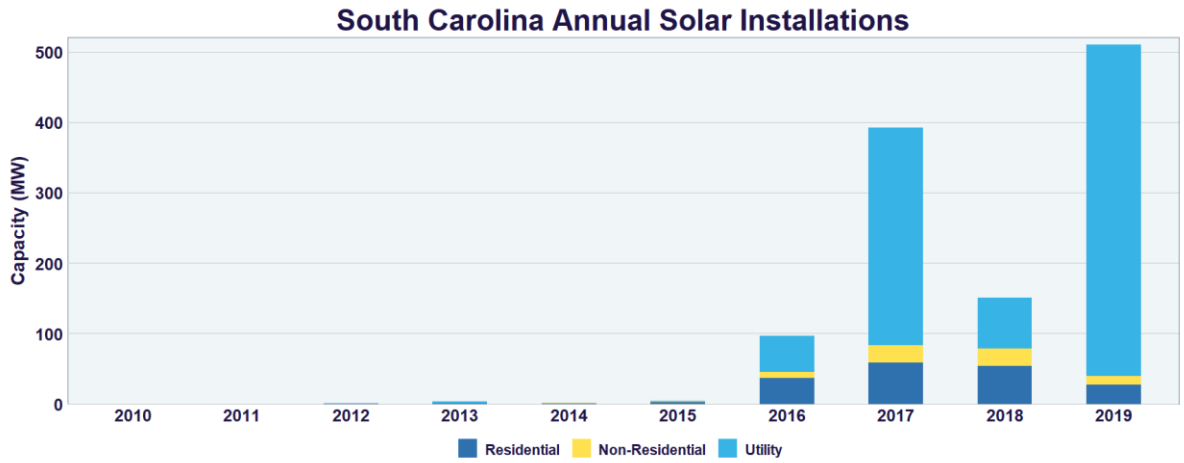


Figure 2 South Carolina annual solar installations (Fox et al., 2018)

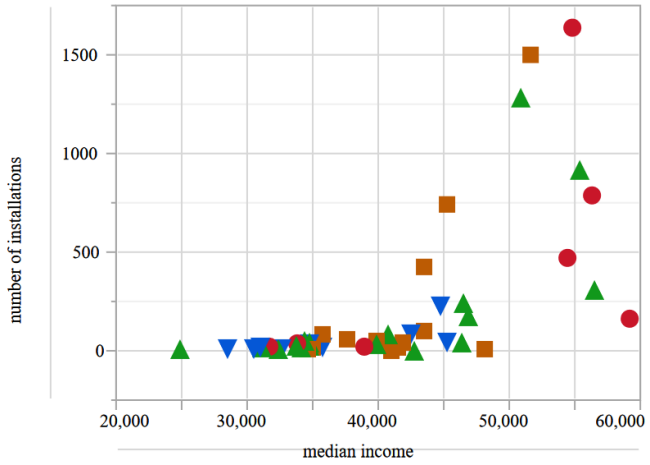


Figure 3 Comparison of number of installations versus median income for 2017 (Fox et al., 2018)

The Energy Freedom Act

The Energy Freedom Act discontinued the incentives described above for IOU, and prohibited charging non-participating customers for any costs incurred in community solar projects. Although the act encouraged the adoption of community solar, it did not include an explicit mandate for IOU to offer the program for residential customers. However, the act stated the intention of the general assembly to support access to solar energy options for all South Carolinians, including those who lack the income to afford the upfront investment in solar panels and those who do not own their homes or have suitable rooftops. Furthermore, the act established that the commission shall promote access to solar energy projects for low- and moderate-income customers. This legislative framework opens the door for the PSC to regulate shared solar projects and create incentives and policies to enable participation of LMI households.

Currently, the offer of shared solar capacity in the State for residential customers is on hold. In South Carolina, and generally in all regulated markets, IOU have only offered the program if there is a legislative or regulatory mandate (Funkhouser et al., 2015, p. 98). Given that the Energy Freedom Act did not include a specific mandate, the new integrated resource energy plans of the three IOU did not include new shared solar projects in the State, at least for the next three years. Although Electric Cooperatives and Santee Cooper have voluntarily offered shared solar programs; Electric Cooperatives are still developing their 5MW community solar goal, and do not plan on new significant expansions. The state-owned utility Santee Cooper has not announced new projects, and do not have plans to do it soon.

Finally, the Energy Freedom Act introduced a voluntary renewable energy program similar to a green tariff that requires IOU to allow participants to enter into contracts with renewable energy facilities for the procurement of energy. The IOU acts as an intermediary, allocating the credit to the customer' energy bill, and receiving the payments from the customer to the renewable energy producer. This program is only available for industrial and commercial customers with a demand of at least 1Megawat (MW).

Current voluntary energy programs in South Carolina and LMI access

Duke Energy submitted a voluntary renewable energy program called Green Source Advantage (GSA). This is a green tariff type program where non-residential customers can contract with developers the provision of renewable energy sources (Duke Energy LLC, 2018). The GSA customer pays its usual rate schedule bill, plus the product charge agreed with the developer and an administration fee for Duke Energy. Duke Energy passes the product charge to the developer and credits the GSA customer with the energy produced by the facility. The bill credits are set at the day-ahead real-time hourly rate, as calculated by Duke Energy. The Renewable Supplier also gets compensated at the hourly rate.

For the residential sector, pursuant the Distributed Energy Resource Program Act, the three principal IOU developed 20 MW of shared solar with the incentives previously described. The programs generated savings for all customers, and LMI customers did not pay upfront subscription costs for the program, which increased their savings. The programs define LMI customers as those with annual income less than 200% of the poverty threshold; they benefited 566 LMI households with a total of 1.8 MW of capacity. Although Electric Cooperatives and the state-owned utility Santee Cooper did not benefit from the mentioned incentives, they also developed 8MW of community solar capacity. However, they did not explicitly include LMI customers in their projects.

Table 2. Current Community solar capacity and LMI access in South Carolina

Utility	Installed capacity kW
Duke Energy Progress	3000
Duke Energy Carolinas	1000
Lockhart Power Company	0
Dominion South Carolina	16000
Santee Cooper	3000
Cooperative Electric utilities	5000
Municipal utilities	0
Total Community solar capacity	28000

Table 3. Low- to -moderate income shared solar capacity in South Carolina

LMI capacity	Installed capacity kW	Subscribed capacity	Remaining capacity	Households
Duke Energy Progress	400	10	348	200
Duke Energy Carolinas	400	52	390	200
Dominion South Carolina	1000	1000	0	166
Total LMI	1800	1062	738	566

Duke Energy Carolinas entered into power purchase agreements (PPA) with two sites for a total of 3MW for their shared solar program. Duke Energy Progress entered into a PPA with a 5MW facility to comply with its utility-scale solar requirement of the Distributed Energy Resources Act and dedicated 1MW to the shared solar program. According to the settlement agreement in the Order 2015-514 and Order No. 2015-515, the companies reserve 400kW for LMI subscribers.

Program participants pay an application fee of $20, a subscription charge of $50 per kW subscribed, and a monthly solar fee of $6 per kW subscribed. In exchange, the participant receives a monthly bill credit of 6.25 cents per kWh produced by their share in the solar facility. For example, if a non-LMI residential customer subscribes 6kW, pays $20 for application fees, and $50 per kW subscribed, in total, the customer pays $320 upfront. Additionally, the customer pays a monthly fee of 6 cents per kW, this is $36 monthly and receives credits based on the production of the subscription. In a given month, the solar share can produce $63.42 in credits, which covers the $36 monthly fee and generate savings. The customer could finish paying the

upfront payment in a year and accumulate the savings throughout the rest of the subscription. An LMI subscriber has the same deal, but they do not have to pay the initial subscription charge, and they have a subscription limit of 2-kW. LMI customers can expect annual savings of about $244.

Dominion Energy selected Clean Energy Collective to operate three shared solar facilities, of 6MW, 8MW, and 2MW. Of this capacity, 5.5MW was residential with 891 non-LMI accounts, 1MW for 166 LMI subscribers, and 9.5 MW for non-residential subscribers. Non- LMI customers must pay upfront 2.25 per watt and receive 10 cents per kWh, the investment takes around 13 years to recover. LMI customers have an average capacity of 6.2 kW per customer and would save approximately $114 each year (Dominon Energy, 2020). The program also requires LMI customers to complete a complimentary Energy Efficiency Home Energy Check-up before subscribing. According to the utility, this can provide approximate energy savings of 907kWh, which doubles the value from a solar subscription(Street & Francisco, 2018).

South Carolina state-owned utility Santee Cooper has a 3MW shared solar project. The utility offered rebates to support all subscribers, with the incentive subscribers pay $410 in upfront costs, instead of $1610, and fixed charges of $4.4 per kW for transmission and distribution systems. In return, the subscriber receives 10.64 cents per kWh. The program does not target LMI customers.

Central Electric Cooperative also lunched a 5MW solar program in 2016, with each electric cooperative installing solar facilities from 50kW to 250kW. Each utility defines subscriber payments and compensation. For example, Blue Ridge Electric Cooperative has a shared project of 250 kW. Each customer can subscribe for up to 5 kW paying an initial administrative fee of $30, an upfront payment of $50 per kW subscribed, and monthly payments of $14 per kW. In return, the customer receives 10 cents per kWh produced by their share.

Shared Solar regulations structure

There are 40 states with at least one community solar project. Out of these 40 states, 18 states have adopted specific legislation and regulatory frameworks with mandatory shared solar programs (Cook & Shah, 2018b). These regulations include eight key aspects (Cook & Shah, 2018b):

1. **A mandate for investor-owned utilities to offer shared solar programs** to their customers or a mandate to buy energy from shared solar developers. This mandate generally includes a competitive procurement requirement.
    - ✓ Competitive procurement: In vertically integrated energy markets, the regulation aims at creating or simulating market conditions to procure renewable energy close to the market price. States such as Virginia and California require IOU to adopt competitive procurement for shared solar programs.

2. **Program cap or mandatory goal**, which is the overall capacity limit or goal established for a statewide shared solar program.
3. **Individual project size cap**. This cap stablishes that Shared solar projects can range from 100kW up to 20MW in size. Connecticut, New Hampshire Massachusetts, Maryland and North Carolina allow facility between 1MW and 5MW. Rhode Island allows up to 10MW, and Vermont allows facilities up to 500kW (Cook & Shah, 2018b).
4. **Subscriber location requirements**. Identify which subscribers can participate in a share solar project based on where the customer is located. Most states require subscribers to be within the utilities' service territory; others, such as California, require projects to be in the same or adjacent county as subscribers.
5. **Quantity of minimum subscribers required** and how much capacity individual customers can purchase. It is cheaper for developers to subscribe a larger portion of the solar array to few customers than across multiple residential accounts. Setting a maximum single subscriber level may limit one participant from holding a majority of the project capacity (National Renewable Energy Laboratory, 2014).
6. **Subscriber compensation or tariff**: It determines the value that the utility must pay to the customers for the generation from their subscription in a project.
7. **Subscription period**. Some states require a minimum of 1 to 2 years, and the maximum is generally 20 years or the length of the Power Purchase Agreement with the renewable energy provider. In South Carolina, the existing community solar projects of electric cooperatives allow for a 20 years subscription.
8. **LMI stipulations establishing**:
    a. Thresholds for lower-income customer participation in shared solar projects.
    b. Subscription conditions and incentives.

For example, in 2017 the North Carolina General As-assembly passed the Competitive Energy Solutions for North Carolina bill (HB 589), requiring each public utility to offer a community solar energy program in their territories. The program should be available on a first-come, first-served basis until the total nameplate generating capacity of those facilities equals 20 megawatts (MW). Therefore, Duke Energy Progress, Duke Energy Carolinas, and Dominion Energy must provide a total of 60 MW of community solar in the State. Utilities should compensate subscribers at avoided cost, and hold harmless customers who do not subscribe to the program.

LMI access policies to shared solar and rooftop solar

As discussed before, to include LMI households in solar projects, regulations must include thresholds for lower-income customer participation, as well as subscription conditions and incentives. States have developed different strategies to facilitate LMI access to solar:

1. Carve-outs. One of the most common policies, these programs reserve a fraction of the program capacity for LMI customers. States have developed requirements from 5%-20%, or higher. If the State does not support the additional costs generated by the carve-out, non-LMI subscribers might bear the additional costs (Heeter et al., 2018).
2. Direct subsidies for developers and electric cooperatives to build LMI solar facilities.
3. Credit options such as credit enhancement, lost loan reserves, interest rate buy-down programs and low interest credits. Incentives can target developers or eligible low-income subscribers when there are up-front payments.
4. Using WAP and LIHEAP funds to fund rooftop- solar installations

States like Colorado and California are an example of carve-out policies where the regulation requires certain procurement for LMI customers. Other states like Michigan, Colorado and North Carolina have granted direct subsidies for short term pilots tailored for electric cooperatives.

Carve-outs

Colorado carve-out

In 2010 the State enacted the Community Solar Gardens Act (HB 0-1342, 2010), Community solar gardens are solar electric facilities of less than 5 MW, where the electricity generated belongs to the subscribers of the project. Subscribers must receive full retail credit for their portion, minus a reasonable charge to cover the utility's costs of delivering the electricity from the garden to the customer. Each IOU had to issue standard offers to purchase 6 MW from community solar gardens between 2011 and 2013. The Public Utilities Commission (PUC) set incremental purchase requirements for 2014 and beyond. The regulation of the law established that IOU must reserve at least five percent of its renewable energy purchases from community solar gardens for eligible low-income subscribers (2015).

In 2014 the PUC directed Xcel to acquire between 19.5MW and 90MW of community solar gardens by the end of 2016. Excel declared Sun Share, Clean Energy Collective and Community Solar Energy to be the three winning bidders of the company's 2015 competitive solicitation for 29.5 MW of community solar (Department of Regulatory Agencies, 2016). In 2016 Xcel completed 1.548 MW of capacity allocated to 364 low-income customers (Xcel Energy, 2017). In 2016, the Colorado PUC approved a new settlement for an additional 117 MW of community

solar gardens. From this capacity, approximately 15 percent (18 MW) will be allocated towards low-income households.

In 2015 Lotus engineering conducted a study (2015) of the Colorado carve-out policy. The study reported that by 2015 there were 20 solar gardens with a generation capacity of 17.687 MG located within IOU Colorado territories. Of this capacity, 890 kW (5.03%) served 349 low-income subscribers with approximately 2.55 kW per household. The study reported that most of the developers covered the 5 percent carve-out, giving free panels away. At a price of $3.00 per wat to $3.50 per W, a capacity of 890 kW for low-income customers costs between $2,670,000 and $3,115,000.

The study had limited access to data regarding the exact savings that low-income households achieved through their subscription. They analyze the estimates that Grid alternatives provided on their LI subscribers in Xcel territory. The subscribers pay a monthly fee for the program of $6.75 and receive a $0.07445 solar credit per kWh their subscription produces. The subscription can offset between 60 percent and 120 percent of their energy consumption. If a customer pays $733 per year for electricity and consumes 5829 kWh per year, offsetting 60 percent saves $260 a year, and offsetting 120 percent saves $520. They conclude that in year one, the program saved 349 households an amount of $90,740 to $181,480.

Without any additional incentives, developers offset the costs of subscribing to LMI customers with higher costs for non- low-income subscribers and anchor subscribers. For example, an anchor subscriber may subscribe to 40 percent of a facility and agree to subscribe to an additional 10 percent to decrease the default risk of LMI participants. Without any state incentive, it might be necessary to allow for a smaller percentage of LMI participants in proportion to non-LMI participants (Interstate Renewable Energy Council, 2016).

California carve out/ green tariff

Senate Bill 43 of 2014 enacted the California Green tariff/Shared Renewable Program (GTSR). The goal was to "expand access to all eligible renewable energy resources to all ratepayers who are currently unable to access the benefits of on-site generation. "The law established a goal of 600MWof shared solar and set aside 100 MW to serve low-income customers in areas with socioeconomic vulnerability, and areas disproportionately affected by environmental pollution and other hazards. The GTSR program is expected to result in a premium cost for participation of at least 2 or 3 cents per kWh (Interstate Renewable Energy Council, 2016). To encourage LMI subscription, in June 2018, the California Public Utilities Commission created two programs for disadvantaged communities. The Disadvantaged communities Green- Tariff (DAC-GT) and the Community solar Green tariff (CS-GT). The intend of the program is to "ensure that low-income households in DACs have similar opportunities as other households to access clean and innovative energy offerings" (Rulemaking 14-07-002, 2018).

The DAC-GT offers eligible subscribers' access to 100 percent renewable energy and savings of 20% on their electric bill. For the DAC-GT program, projects must be allocated 100 percent to LMI. In contrast, the CS-GT program allows to subscribe 50 percent of no-LMI customers, but requires to locate projects close to subscribers. The community version requires local sponsors that will engage local jobs for the projects. Projects must be between 500kW and 1MW and allocated through a competitive process. Utilities have just started complying; through September 2019, there were 151MW of community solar capacity and only 2MW in disadvantaged communities.

IOU must submit a detailed methodology of all above-market costs of each program (Resolution E-4999, 2019). Costs include, (1) Cost premium, if any, for the net renewable resource costs used to support the program that is more than the customer's otherwise applicable class average generation rate. 2) Revenue loss associated with the 20 percent savings on the total bill to participating customers. 3) administration and outreach costs. These costs will be funded with the Greenhouse Gas Allowance and with public purpose program funds (Pacific Gas and Electric Company, 2018)

Direct subsidies for electric cooperatives

Colorado

In 2015 The Colorado Energy Office (CEO) launched a community solar pilot for low-income households. Cooperative utilities developed eight solar garden installations with a total nameplate capacity of 1486 kW. The pilot program served 380 subscribers, and the average annual cost savings per subscriber were between 15 and 50 percent, with average savings of $382 per year per subscriber (Hillary Dobos & Emily Artale, 2017). The program required the subscriber's homes to be previously weatherized generally through the WAP program.
Some projects installed the panels in brownfields, which generated additional cost savings. Utilities covered the capital costs with a CEO grant of 1.2 million and 2.01 million of internal funding from the utility and or financing acquired by the utility. Only one of the largest projects achieved the necessary scale to bring in third-party financing tax equity. None of the cooperatives could advantage from the Modified Accelerated Cost Recovery Schedule. If the utilities had been able to take advantage of these incentives, the return for each project would have increased by $123,000.

Michigan

The Michigan Agency for Energy received funds from the U.S. Department of Energy's Clean Energy for Low-Income Communities Accelerator to develop a community solar pilot. The agency selected Cherryland electric cooperative for a 150-kW project. The total cost was $270,000. The Energy Agency granted $80,00, and the remaining $190,000 came from the cooperative. Fifty families with incomes below 200 percent of the federal poverty line were part

of the program, each with 3 kW of capacity, and an enrollment period of 15 years. Each account receives a credit of 10 cents for each kilowatt-hour produced by the solar array. Annual bill credits are expected to be around $350 per household per year. Homes must be previously weatherized or must have an energy audit indicating that there are not additional cost-effective energy efficiency interventions to pursue. Energy efficiency will generate 15 to 40 percent of the savings, and solar credits will increase savings as much as 70 percent. (Eric Cody, 2019).

The pilot leverages the strong, well-established relationships of the electric cooperative with the local community action agencies. Cherryland administers solar participation, credit calculation, and program tracking, while the local community action agency delivers weatherization services, house audits, and income verification. Finally, Cherry cooperative calculates losses of $17,500 annually ($350 average bill credits times 50 participating households), which expects to recover from reduced energy purchases from its wholesale provider.

Credit Options

Massachusetts credit strategy

The Mass Solar Loan program in Massachusetts incentivizes lenders to offer attractive solar loans, mitigating lender risk via Interest Rate Buy-Downs, Income-Based Loan Support, and a Loan Loss Reserve. Eligible participants are those at or below 80% of the State Median Income, and both on-site and shared solar projects qualify. The Program has a $30 million fund from the Alternative Compliance Payments received by the Department of Energy Resources under the Massachusetts Renewable Portfolio Standard. The state agency Massachusetts clean energy Center (MassCEC) determine System Owner eligibility, and lenders cooperate with loan underwriting.

The interest rate buy-down covers part of the interest rate payments for beneficiaries. The Interest rate that the lender offers before the subsidy cannot exceed WSJ Prime plus 2.75 percent (currently 6 percent). At the beginning of the program, the rate buy down was three percent, then it was reduced to 1.5 percent. This program has 5 million dollars allocated

For the loan loss reserve, MassCEC designated a cash reserve for each participating lender according to their credit score. For those with a credit score between 681 and 719, 10% of the program loan will be allocated to the LLR. For those with 680 and below, 20% of the program Loan will be allocated to the LLR. Finally, the Income-Based Loan Support Payment will pay a percentage of the lesser the Program Loan Amount; the program has 10 million dollars allocated.

Using WAP and LIHEAP funds to fund rooftop- solar installations and community solar

The Colorado Energy Office developed a low-income rooftop solar program using WAP and LHEAP resources. WAP funds are restricted to specific approved weatherization measures. To gain approval from the Department of Energy to use WAP funds to install solar rooftop, the energy office had to demonstrate savings to investment ratio (SIR) greater than 1.0. The SIR is calculated, dividing the total saving over the project's useful life by the cost of the project. The SIR must be at least one, which indicates that a household can recover the investment.

Using LIHEAP resources is more flexible because LEHEAP resources do not have specifically approved weatherization measures. Regulation allows any low-cost, cost-effective weatherization that does not constitute construction. The Colorado Energy Office used LIHEAP sources destined to weatherization for solar rooftop in projects where the investment was cost-effective (Cook & Shah, 2018a).

Due to higher prices and more complex individual installation process, the low-income rooftop program in Colorado connected only 300 homes from 2017 to 2019. The beneficiary homes also received weatherization work from WAP and energy-efficient appliances and lighting measures. On average solar accounted for 41% of the savings followed by efficient appliances and lighting.

In New York, all LIHEAP customers receive community solar subscriptions

METHODOLOGY

The objective of this report is to propose, analyze, and evaluate policy options to address the lack solar energy options for LMI households. The next section introduces four criteria to evaluate the proposed alternatives. Each alternative will be described and assessed according to the selected criteria; results will be presented in an outcome matrix. The next sections will discuss the final recommendation based on the evaluation process and implementation aspects of the selected option.

CRITERIA

This report uses 3 criteria to evaluate the likely outcomes of each alternative. This study includes cost-effectiveness, political feasibility, ease of implementation, and avoided cost emissions. The subjective criteria political feasibility and ease of implementation will be weighted to reflect its importance in formulating the final recommendation.

Costs-Effectiveness

Total cost to implement the alternative includes the installation costs of the systems and the operational costs incurred by the utility to administer the program. The effectiveness is the amount of total energy produced by the solar facilities thought 20 years. Both costs and total energy production are discounted at a 7% rate. A cost-effectiveness ratio is calculated, dividing the total cost of the program by the total energy production to obtain dollar costs per kWh. Additional to cost-effectiveness, this section analysis the distribution of costs among stakeholders in each alternative to achieve LMI inclusion.

Political feasibility

This criterion evaluates the level of support by decision-makers, specifically, the South Carolina Public Service Commission, and the South Carolina Legislature. The criterion analysis the likelihood of securing sufficient funding, and the support of the utilities. It also evaluates how well the alternative aligns with the Energy Freedom Act mandate to expand solar energy access for LMI households. The information to assess each alternative will derive from the legislative history of the State, interviews with stakeholders, and experiences in other states with the specific alternative. This criterion is measured as high (score 3), moderate (score 2) or, low (score 1) political feasibility, and weights 60% in the final evaluation.

Ease of implementation

This criterion evaluates the complexity of the alternative, the administrative burden for the State and for utilities, and the timeline needed to develop each alternative. Each alternative can be evaluated as high (score 1), moderate (score 2), or low (score 3) implementation complexity. This criterion weights 40% in the final evaluation.

Net present value of emissions avoided

This criterion measures the costs saved through solar generation. For this criterion we calculate the total generation from solar installations, and then we estimate the emissions avoided based on the emissions per MWh from the South Carolina electricity grid. Finally, I estimate the costs using the social cost of carbon described in the cost to society section. The details of this estimates are in Appendix C.

ALTERNATIVES AND EVALUATION

1. status quo

This alternative consists of letting the present trends continue. Those families without technical conditions for rooftop solar will be excluded from the solar energy market. Without financial incentives, LMI families with technical capabilities to install rooftop will still lack the upfront capital to access solar rooftop.

The energy Freedom Act did not establish a mandate or a specific regulatory framework for shared solar projects. According to the Integrated resource plans of investor-owned utilities, shared solar projects are not in the foreseeable future. Electric cooperatives are still developing their 5MG goal, and the state-owned utility Santee Cooper does not have plans to develop new shared solar projects. The lack of a specific regulatory framework hinders the private investment in these types of projects and reduces the certainty necessary to invest. The current policy and market atmosphere in South Carolina will not facilitate the adoption of solar by LMI households in the foreseeable future.

Evaluation

Cost-effectiveness

Under this alternative, there will be no incremental cost, and there will be a minimal expansion of solar in low-income communities. Any access will be due to social mobility and access to credit of LMI customers. **Cost-effectiveness is $0**

Political feasibility

This alternative does not comply with the legislative mandate from the Energy Freedom act to enable access to solar energy for those without adequate rooftop space, renters, and low-to-moderate-income households. Therefore, this alternative has a low political feasibility

Score: 1

Ease of implementation

This alternative does not need any additional administrative resources. This alternative has a low implementation complexity.

Score: 3

NPV of emissions avoided

$0

2. Require IOU to offer shared solar programs for residential customers and integrate an LMI carve-out. Non-low-income subscribers will cover the extra costs associated with LMI subscriptions.

In this alternative, the Public Service Commission will require Investor-owned Utilities to offer shared solar programs enabling ratepayers to participate directly in off-site generation facilities. Under this alternative IOU develop 60MW and allocate 15.855 MW to 4530 LMI homes with previous weatherization work; each household has 3.5 kW of capacity. The rest of the capacity is allocated to non-LMI residents or commercial customers, who pay a fee to support the extra costs associated with the LMI access program. The cost distribution section explains in detail the extra cost for each non-LMI participant. Assuming the elevated cost of the program and residential subscriptions only, the program will require 13,590 non-LMI residential customers to pay $174 extra each year to cover the cost associated with LMI subscriptions.

To enable LMI customers to subscribe to the program, the payment per kWh should, first not exceed what they currently pay, and second, generate savings in their energy costs. The California Public Utilities Commission, and the Maryland Green Bank, targeted 20% saving to incentivize low-income customers to subscribe to share solar. Applying the same savings target to the current average retail rate in South Carolina ($0.1244), the target rate for LMI subscribers would be $0.0995 per kWh.

The design of the program will determine if subscribers pay a premium for the program or if it will generate net savings. If there are premium costs to participate in the program, non- low-income subscribers will cover the premium costs of the program for low-income subscriptions. Additionally, non-low-income subscribers will cover the extra costs associated with 20 percent of energy cost savings guaranteed for low-income subscriptions in the program.

A vital aspect of this alternative is that utilities must be able to recover all the costs associated with the program through the kWh price. Under this alternative, the PSC adopts a similar cost recovery model as California shared solar/green tariff. The price of each kWh must include:

1. Tariff for the Renewable Power Rate
Once the renewable energy projects for the program achieve commercial operation, the rate will be the incremental cost of those new projects per MWh.

2. Indifference fee
The energy freedom act requires to leave unharmed ratepayers that do not participate in community solar programs. The fixed costs of additional services such as transmission and distribution, must not be shifted from participating customers to non-participating ratepayers. To prevent cost-shifting, the California Public Utilities Commission adopted a Power Charge Indifference Adjustment (PCIA) that subscribers that unbundle from the grid must pay

3. Administrative and marketing fees
Administrative costs include the use of the call center, billing staff, marketing materials, subscription time, among other expenditures of the program.

This alternative draws from the Community Solar Gardens program in Colorado. The initial phase of the program required a 5 percent LMI carve out in each shared solar project. During the first years of the program, the State did not allocate funds to support the carve-out. Developers usually transferred the cost associated with LMI subscriptions to other residential subscribers. Another option is to engage creditworthy non-residential anchors to subscribe to a large portion of the project's capacity. Without any other state incentive, utilities can use this alternative to finance the low-income carve-out, without harming non-participant customers.

This alternative also appeals to crowdfunding ideas, where the capital comes from donations. In this case, the voluntary donations will come from other subscribers or anchor subscribers or anchor subscribers. The State has previous experience with this type of initiative with the program called Palmetto Clean Energy. For this initiative, the Energy office of South Carolina coordinated with the three IOU and created a non-profit to administer 4 dollars donations from ratepayers to develop renewable energy capacity.

Evaluation

Cost-effectiveness

In order to reach 4350 LMI families under this alternative it is necessary a total capacity of 60MW. The total administrative and installation cost of the program with this capacity is $118,552,203.94 through 20 years. The total energy output of this capacity will be 935,663 MW in 20 years. Thus, the cost-effectiveness of this alternative **is $0.1273 per kWh** without federal subsidies.

This alternative proposes systems with a capacity higher than 500 kW that can easily take advantage of the federal incentives. Taking into account the Federal energy investment tax credit (26%) and the Modified Accelerated Cost Recovery System, the total cost of the program is $71,537,463.94, which renders a cost-effectiveness of **$0.0771 per kWh.**

Cost distribution

As described above, participants to the program will bear all the costs of the program through the prices they pay for each kWh. Additionally, to support LMI subscriptions, non-LMI customers will cover the extra costs associated with LMI plus the target savings.
Since the cost per kWh varies from project to project and depends on the PV technology, facility capacity, and terrain. Table 5 shows three possible price scenarios of the program costs the average and the upper and lower bounds. I use the public costs (Appendix A) of the California Green Tariff/ Shared Solar to model three scenarios.

Table 4. Shared solar fees in three scenarios, average costs, upper bound, and lower bound costs.

	Cost of solar energy purchase per kWh	Administrative and marketing fee	Indifference Fee	Total Program Cost per kWh	S.C Residential Rate per kWh	Program Cost - S.C Residential Rate difference	% Change
Average	0.0647	0.0192	0.0279	0.1117	0.1244	-0.0127	-10.180
Upper bound	0.06718	0.02956	0.03237	0.1291	0.1244	0.00471	3.786
Lower bound	0.062	0.00995	0.00995	0.0819	0.1244	-0.0425	-34.164

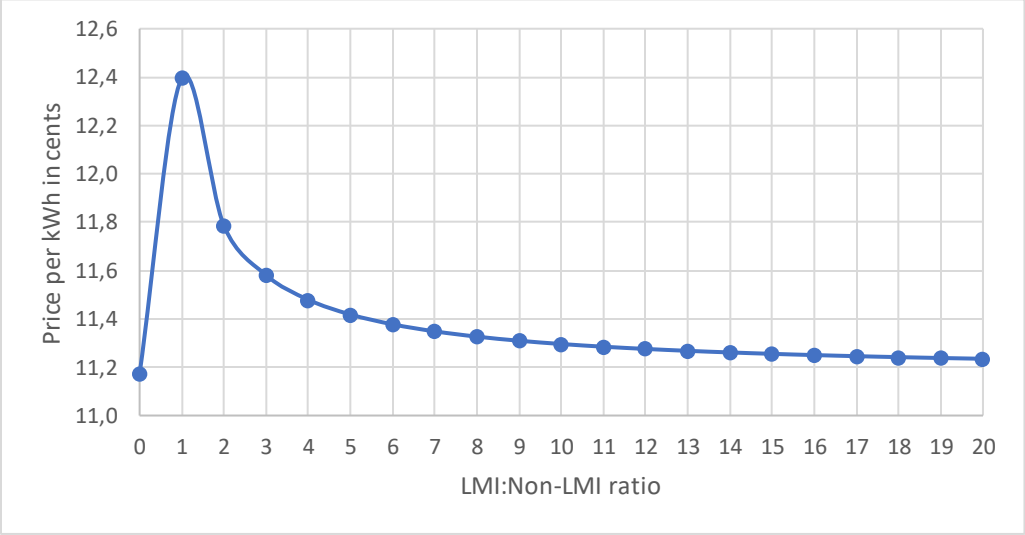
With the lower bound assumptions, the 20 percent savings goal is exceeded, thus not cross-subsidy is needed. In the average scenario the program tariff for subscribers is $0.1117 per kWh, which represents 10 percent savings compared to the average residential rate of $0.1244. There is

still 10 percent missing to achieve 20 percent savings for low-income subscribers. As described, non-low-income subscribers will cover the difference ($0.0122)

The ratio LMI: Non-LMI determines the non-LMI payments to support LMI subscription. In a 1:1 ration, each non-low income will have to pay $0.0122 additional per kWh to complete 20 percent savings for one LMI subscriber. If the ration increases to 1:2, the cost of one LMI subscription will be divided between two non- LMI subscribers. Thus, each non-LMI will pay $0.1117 plus $0.0122/2. Figure 4

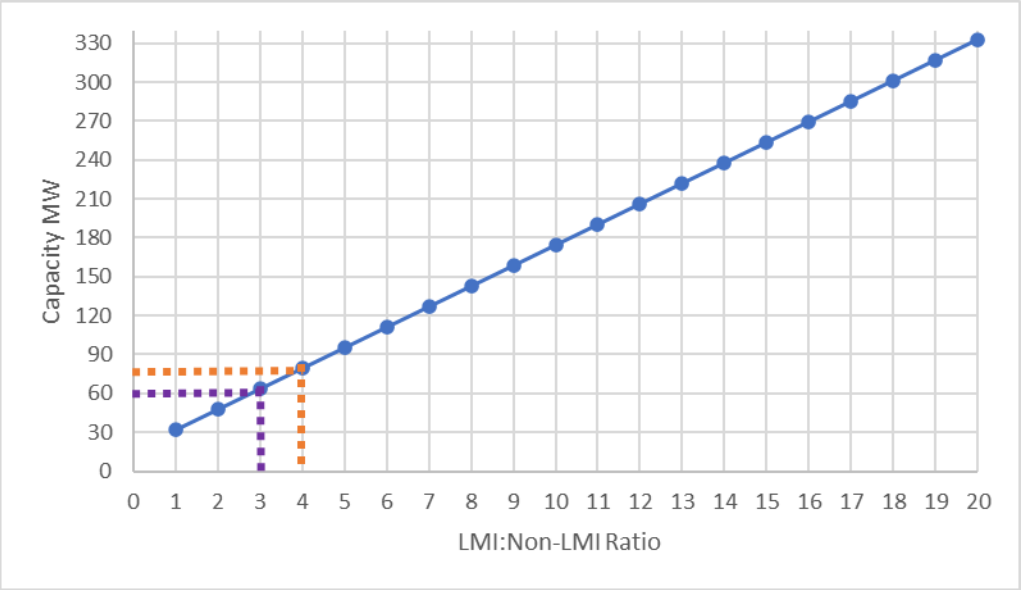
Figure 4 shows how the LMI: Non-LMI ratio changes for the average price scenario.

Figure 4. Non-LMI rate charges versus the LMI: Non-LMI ratio, in the average fee scenario



The required capacity generation to guarantee shared solar energy for 4,530 LMI households depends on the LMI: non-LMI ratio. In a 1:1 ration to subscribe 4,530 low-income families, the program will have to enroll the same number of non-low-income families. In the 1:20 scenario, to subscribe 4,530 low-income families, the program will need to enroll 90,600 non-low-income families. To provide each household with 3.5 kW of capacity, the first scenario will need to develop 31,719 kW (4530 families *2*3.5kW). The second scenario will need a capacity of 332,955 kW (4,530*20) +4,530 *3.5kW).

Figure 5. Capacity required versus LMI: Non-LMI ratio.



To understand realistic bounds for shared solar capacity in the State of South Carolina, this work extrapolates the capacity goals of California and North Carolina. In California the goal is to generate 600MW of share solar for 39.51 million people. In North Carolina, the utilities are required to install a combined capacity of 60MW for x people. Using this numbers as a reference, a realistic capacity to serve the population of South Carolina is between 60 MW and 80MW. Figure 5 shows how the required capacity depends on the LMI: Non-LMI ratio. For a capacity of approximately 60 MW, the LMI: Non-LMI ratio must be 1:3 (purple dashed line). Similarly, for a capacity of approximately 80MW, the LMI: Non-LMI ratio must be 1:4 (orange dashed line).

Figure 6. Change in Savings for non-LMI versus LMI: Non-LMI ratios for the average scenario

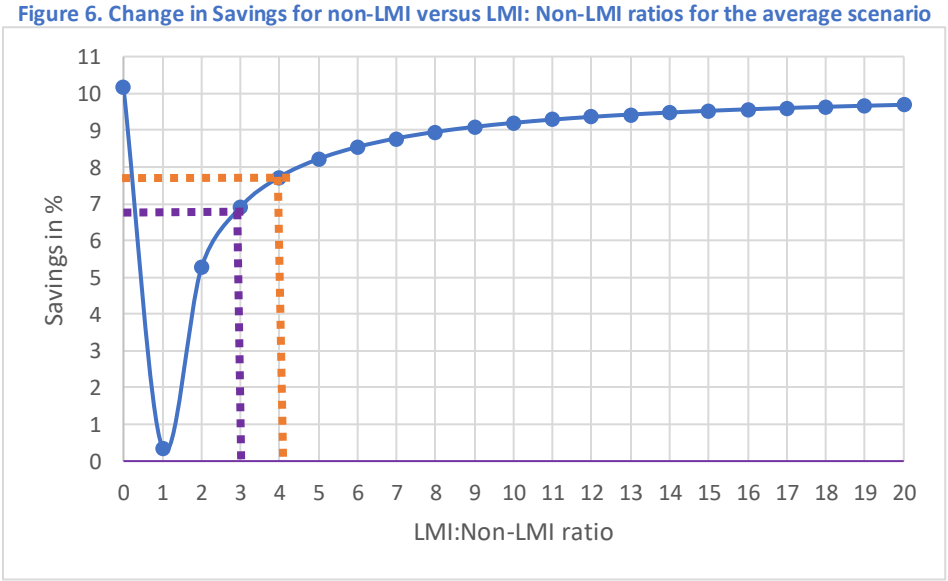


Figure 6 shows the savings in percentage that non-LMI will obtain for different LMI: Non-LMI ratios. With a ratio of 1:3 corresponding to a capacity of 63.4MW, non-LMI customers still obtain 6.9 percent of savings. With a ratio of 1:4 corresponding to a capacity of 80MW, non-LMI customers still obtain 7.7 percent savings.

A LMI: Non-LMI 1:3 ratio needs a total capacity of 63.42MW, and at least 13,590 non-LMI subscribers to offer shared solar to 4,530 LMI customers. This arrangement has the following impact on non-LMI subscribers:

Table 5. Savings or extra-costs for non-LMI subscribers with a 1:3 LMI: Non-LMI ratio

Fees assumption	Program Tariff per kWh with LMI support 1:3	Increment	Non-LMI savings (-) or extra payment	% Change S.C Residential Rate
Average	0.1158	-0.00859	-103.093	-6.91
Upper bound	0.1389	0.01457	174.88	11.71

In the upper bound scenario, non-LMI subscribers will have to pay $174.8 extra each year, which is 11.7 percent higher than what they usually pay with the average residential rate in South Carolina. In the average fee costs scenario, non-LMI customers will still save $103, which represents 6.9 percent savings.

Political feasibility

Because the alternative does not require public funding and guarantees that other ratepayers will not bare extra costs, the Public Service Commission is likely to approve this mechanism as an alternative to encourage LMI participation in shared solar programs.

Utilities will likely support the program only if they fully recover the costs of the program through rate structure. The proposed model guarantees full cost recovery through rate structure. Furthermore, this will be an integral shared solar policy that will also expand solar choice for the non-LMI customer.

Access to shared solar and cost savings for LMI customers depend on the subscription rate of non-LMI. In the upper bound case, non-LMI subscribers will have to pay $0.014 extra per kWh, which is $174.8 extra annually. The extra payment will decrease the non-LMI demand of the program. In this case, utilities will have to implement strong marketing and information campaigns to explain the environmental benefits of the program as well as the support given to LMI subscribers. A study of residential demand for green energy found that the price elasticity of that demand is highly inelastic: when price increases by 1%, demand decreases by almost 0.3% (Dagher et al., 2017). Therefore, we can expect that if the program keeps the price sufficiently low, non-low-income customers will still be interested in the product, even paying a premium.

Residential rate premiums for green tariffs in the U.S range from $0.002/kWh to $0.08/kWh, with an average of $0.019 (O'Shaughnessy et al., 2018). Many programs in the State have exceeded 15,000 participants, with annual extra charges ranging from $87 to $328. For example, The Green Power for a Green LA program charges $0.03 extra per kWh, which represents $328 extra annually, and had a little less than 20,000 participants in 2013 (Matek, 2016). A price per kWh below the national average can guarantee the minimum non-LMI required subscription. In this case, the premium is $0.014, which is below the national average.

A drawback of the policy is that the regulatory jurisdiction of the Public Service Commission only covers IOU. Electric cooperatives will not be required to adopt a shared solar. This is a lost opportunity because electric cooperatives in the United States serve in more than 90 percent of the nation's Persistent Poverty Counties, which are counties identified by the U.S. Census Bureau as having a very high percentage of households with incomes below the poverty level.

This alternative does not require new public funds to finance LMI subscriptions, and utilities will recover the total cost of the program from subscribers. Furthermore, the extra payment for LMI assuming high cost of the program will be below the average national premium for green energy. For these reasons, this alternative can be raked with high political feasibility.

Score: 3

Ease of implementation

This policy will require utilities to keep an LMI: Non-LMI ratio of 1:3, which are approximate calculations to guarantee that higher-income subscribers can transfer part of the savings to LMI customers while keeping enough program savings to be willing to join and stay in the program. Shared solar programs also allows retail customers different than homes to subscribe to the programs, such as small businesses, schools, universities, and other entities the key of the policy is to guarantee a structure where those with higher income transfer part of the savings to lower-income customers. The alternative will require constant monitoring of the ratio balance to guarantee LMI benefits and avoid utility losses

The 4,530 homes that have received previous weatherization work from the WAP program are spread through the State. Each utility will work in close collaboration with Community Action Agencies in their territories to identify eligible homes that have received previous weatherization work. Once identified, the utility would be able to project the number of eligible LMI households and calculate the ratio of LMI: non-LMI subscribers required to finance LMI subscriptions. Utilities and Community Action Agencies should inform the PSC about the number of eligible homes in utilities' territories. The Public Service Commission will also request reports each

semester from the utility explaining the cost distribution between LMI and non-LMI customers in the shared solar programs.

This alternative will require a high level of coordination and monitoring. However, utilities, Community Action Agencies, The Energy Office of South Carolina, and the Public Service commission have enough experience and installed resources. For these reasons this alternative has a moderate complexity

Score: 2

NPV Emissions avoided

The total emissions avoided will depend on how successful the program is after the first implementation period and in subsequent periods. **The total NPV of emissions avoided is $7,248,076**

3. Adopt a direct subsidy for utilities to cover the extra cost associated with LMI subscriptions

For this alternative, the Public Service Commission will also require Investor Owned Utilities to offer shared solar programs. Because new public funds will be allocated to cover the LMI extra cost subscriptions, the South Carolina legislature will need to approve new resources for the program. Assuming high costs of the program, the fund will have to be of at least $10,696,611 to provide 4,530 households with a capacity of 3.5 kW each and savings of 20 percent. The program will require a total capacity of 15.855 MW. All utilities should be eligible for the subsidy to support LMI subscriptions in shared solar projects including, electric cooperatives, and Municipal Utilities. This will enable other utilities to adopt the model and have resources to fund low-income subscribers in their solar share programs.

The access to shared solar in this alternative will not depend on the subscription of non-LMI. The provision of the required capacity depends on how well the subsidy covers the real extra costs of the program to serve LMI households. The subsidy will allow utilities to cover 20 percent of cost savings through the reduced energy tariff after the program, and the direct subsidy. If the incentives cover the extra-costs associated with low-income subscriptions to the program, this alternative will achieve necessary to serve 4,530 eligible families.

Evaluation

Cost- Effectiveness

This alternative only needs to develop solar capacity for LMI customers, for a total of 15.720 MW. Given that the extra costs associated with LMI subscription will be supported by the State it is necessary to take into account the Deadweight loss penalty associated with usage of public funds. "Revenue-raising measures will impose opportunity cost on the community to the extent that they preclude activities and transactions that would otherwise have occurred, with consumer and producer surplus being foregone" (Dobes et al., 2016, p. 203). After taking the deadweight loss into account the cost of 15.720 MW capacity increases slightly to $33,412,365, This capacity will produce 247,249.04MWh, which renders a **cost effectiveness of $0.136 per kWh**.

Political feasibility

In other states, low-income solar programs have been financed with special propose funds. For example, California is financing the Disadvantaged Communities-Green -tariff program through the Green House Gas allowance resources that come from the Greenhouse Gas Cap and trade program. In Illinois, the low-income community solar for all programs budget comes from the Renewable Energy Resources Fund, which is comprised of alternative compliance payments that Retail Electric Suppliers do as part of their Renewable Portfolio Standard obligations.

South Carolina lacks a special propose fund for renewable energy and energy efficiency. It is expected that the Energy Freedom Act mandate to promote access to solar for low-income communities will raise the question of the necessary funding to develop programs. However, a new law to allocate resources is unlikely given that the State just enacted a major legislative reform with the Energy Freedom Act.

Resources from LIHEAP and WAP program, described previously, could be leverages to pay extra monthly costs of the program. Users that benefit from crisis funds to pay electric bills will be automatically subscribing to the shared solar program that will give them 20 percent savings. However, only Colorado has used LIHEAP and WAP funds for rooftop solar, and these resources have not been used for shared solar policies before.

The State lacks specialized funding for energy projects and the possibility of a new legislation to allocate the resources for the fund is unlikely. However, the mandate to enable access to solar energy will require the allocations of funds, it is expected that the funds ultimately will be less than $10,696,611. For these reasons the alternative has a medium political feasibility

Score: 2

Ease of implementation

This alternative has a relatively easy implementation as the utilities will only have to inform the extra costs associated with Low-income subscriptions. A key element of this alternative is transparency from utilities to assess the specific expenditures to achieve 20 percent savings for low-income customers. The report should ensure that all costs and revenues are fully transparent and auditable to provide the resources. This alternative has a low implementation complexity.

Score: 3

NPV Emissions avoided

In this alternative, the resources for the extra costs are more certain therefore the avoided emissions are more likely to materialize. The total NPV of emissions avoided is $ 1,915,305

4. Adopt a rooftop strategy using WAP and LIHEAP funds

The Energy Office and the Office of Economic Opportunity will joint efforts to pursue authorization from the Department of Energy to use funds form the WAP and LIHEPA programs to invest in on-site roof top solar. Families eligible for this program will be those at the or below 200% of the federal poverty to follow the same guidelines of the WAP and LIHEAP programs. The goal is to install 3.5 kW capacity systems in 4530 homes with previous weatherization work. The average annual energy production of a 3.5 kW system is 4,815 kWh. Assuming an annual consumption of 1200kWh the production of the panel will offset 42% percent of the monthly consumption.

The South Carolina Office of economic Opportunity will have to conduct a savings to investment ratio (SIR) to justify using WAP funds to install solar rooftop. A SIR higher than one depends on the price per kWh that the household is paying and the price per watt of the installation. Currently the average retail rate in the State is $ 0.12 per kWh and the average price per watt of residential installation in the State is $3.12. With this assumption the savings to investment ration in a 20 years period is 0.68. The maximum price per wat to obtain a savings to investment ratio greater than 1 is $2.06 per watt. If the State finds vendors with this price, the South Carolina Office of Economic Opportunity will be able to use WAP and LIHEAP resources to finance on-site solar.

The actual savings for LMI families depends on what percentage of those savings will have to be allocated to pay the system. The WAP resources can cover up to $3,598 per unit, the rest will have to be recovered from the customer. The utility will implement on bill payment to recover the other part of the system costs through the savings generated. LIHEP funds will serve as credit enhancement to cover payment defaults, as they currently serve the same propose but for regular utility bills.

Evaluation

Cost effectiveness

Costs associate with rooftop solar are higher due to their scale and higher administrative and labor costs associated with each individual installation. At a price of $3.13 per wat the installation and maintenance cost of a 3.5kW unit costs $11,436. Providing 4,530 the same capacity will cost $51,807,798.29. The total energy produced will be 247,249 MW for a **cost per kWh of $0.20** without federal incentives.

Political feasibility

This alternative requires a lengthy administrative process with the Department of Energy in order to obtain approval for the resources. This alternative does no need direct intervention form the PSC, because the Economic Opportunities Office directly administers WAP and LIHEAP resources and develops the state guides to expend the resources. Utilities will have to finance part of the cost that are not cover through the WAP and LIHEP, or the Federal tax incentives. This aspect might hold back the proposal, however if LIHEAP funds function as loan loss reserve for utilities, they will be willing to act as lenders.

This alternative will use federal government funds and does not need new legislation to operate. However, the approval process is lengthy and the DOE must approve using resources in solar PV. For these reasons this alternative has medium political feasibility

Score 2

Ease of implementation

As explained before 67% of LMI households in South Carolina do not have suitable rooftops, life in multifamily houses, or rent their homes, which highly restricts their capacity to install on-site solar. This program will be available to limited families. According to the Colorado experience only 300 families benefited from the program in the first 3 years. Therefore reaching 4530 families could take 45 years, which is not a reasonable time framework. Furthermore, it requires more detailed logistics tailored to each individual home. This alternative has a high complexity.

Score: 1

NPV Emissions avoided

In this alternative, the likelihood to reach 4530 families and develop the total generation required is very low. The total NPV of emissions avoided is the same as alternative three $ 1,915,305, but with a lower probability

OUTCOMES MATRIX

The outcomes matrix is a visual representation of the alternatives scoring. Each alternative is assigned a numerical score from 1 to 3 for the subjective criteria, political feasibility and easy of implementation. Subsequently, each criterion is assigned a relative weight to account for its importance in determining the final recommendation. A final score is determined by multiplying each score criteria score by the assigned weight, and then adding up the results.

Table 6. Unweighted score results for political feasibility and ease of implementation

Alternative/Criteria	Political Feasibility	Ease of Implementation
Status Quo	Low 1	Low complexity 3
Cross subsidy by Non-LMI	High 3	Medium complexity 2
Direct subsidy for shared solar	Low 1	Low complexity 3
Rooftop solar strategy	Medium 2	High complexity 1

Table 7. Outcomes matrix with weighted scores

Alternative/Criteria	NPV avoided emissions	Cost-Effectiveness	Political Feasibility	Ease of Implementation	
		$/kWh	60%	40%	100%
Status Quo	0	0	0.6	1.2	1.8
Cross subsidy by non-LMI subscribers	$7,248,076	$0.127	1.8	0.8	2.6
Direct subsidy shared solar	$1,915,305	$0.136	0.6	1.2	1.8
Rooftop solar strategy	$1,915,305 (low probability)	$0.209	1.2	0.4	1.6

RECOMMENDATION

It is recommended a model where the Public Service Commission adopt a shared solar mandate for investor owned utilities with a low-income carve out. This alternative has the highest political feasibility, and utilities can recover all associated costs through rate structures. Costs are not shifted to non-solar customers or tax-payers. All program costs are borne by subscribers, and non-low-income subscribers pay the extra cost associated with low-income subscriptions. Although the access to non-LMI to the program depend on the adoption level of non-LMI subscribers, a rate structure with a low premium will still incentivize non-LMI subscribers to join the program. Finally, this alternative has the highest avoided emissions. The Public Service Commission will need further investigation in the cost components of the program and how to achieve the lowest cost for each of them.

The Status Quo, will not increase residential customer choice of renewable energy. Most of the state residential customers cannot install on-site solutions. 67% of LMI households do not have appropriate roofs or space to opt for on-site solutions. Furthermore, IOU have not included in their Integrated Resource Energy plans program to enable residential customer choices of off-site solar. Therefore, the energy market in the State is not satisfying the increasing LMI and non-LMI demand of renewable energy, in particular solar.

The direct subsidy alternative has low political feasibility due to the lack of specific funds for renewable energy in the State. The Energy Freedom act did not stablish any new funds or source of revenue for renewable energy development so finding new sources of revenues for is very unlikely in the State. The Energy Office of South Carolina does not have sufficient resources to support the program either.

The rooftop strategy renders a high cost per kWh of 0.209 thar is 60% higher than the current retail rate of $0.124 per kWh. Furthermore, its implementation requires approval form the Department of Energy which is a time and resource intensive. Furthermore, only 33% of LMI households can support in-site solar and even less have previous weatherization work.

IMPLEMENTATION

Relevant themes regarding the implementation of the policy include:
- Transparency: Utilities in South Carolina have previously implemented subsidized shared solar programs, however, there is not publicly available data on the specific expenses of the program, to evaluate how much more customers will have to pay in the absence of the subsidy. With detail data the Public Service Commission and the Energy Office of South Carolina would be able to understand the specific extra cost of the program in the State. This will inform a more equate determination of the required LMI: Non-LMI ratio needed to serve 4,530 LMI eligible homes. A participating utility shall track and account for all revenues and costs to ensure transparent and auditable pricing of the product

- Accreditation schemes might secure more non-LMI subscriptions. An accreditation scheme guarantees that the supplier is actually procuring renewable energy to the customer, it provides confidence, clarity, and consistency to the consumer. According with a study by (reference) Obtaining accreditation can have boost renewable energy sells by 28.5%.

- Because weatherization is a key element of solar energy solutions for low income households, this alternative need close collaboration with the Community Action Agencies that administer weatherization services for LMI homes with the WAP program. Working together, could reduce administrative costs related to customer acquisition, qualification and retention.

- Location of solar facilities to serve low income communities is a key policy consideration. Illinois have stablished environmental justice communities, which are communities with higher risk of exposure to pollution based on environmental and socioeconomic factors. For example, communities located near coal plants are mayor target locations of state incentives for shared solar. California low income program encourage renewable energy facilities in Disadvantage Communities. Which are areas that most suffer from a combination of economic, health, and environmental burdens. South Carolina can take advantage of Opportunity Zones stablished by Congress as a part of the Tax Cuts and Jobs Act of 2017, they are designed to encourage private investments in lower income communities.

- Competitive procurement is critical for utilities to buy energy at the lowest possible price and transfer lower costs to participant customers. This is not the general practice in South Carolina, instead, avoided cost is the methodology to compensate renewable energy producers.

APPENDICES

Appendix A

California Green Tariff/Shared Renewables Program

Illustrative table of the program charges broken down by charges (California Public Utilities Commission, 2020)

PG&E	Renewable Power Rate	Generation Credit	Program Charges	PCIA	Total ($)	In Cents
GT Residential	0.0648	-0.11777	0.02956	0.02706	0.00365	0.365
GT Small Business.	0.0648	-0.11486	0.02582	0.02705	0.00281	0.281
SCE						
GT Residential	0.06718	-0.08927	0.01993	0.02766	0.0255	2.55
GT Small Business.	0.06718	-0.09034	0.01993	0.02401	0.02078	2.078
SDG&E						
GT Residential	0.062	-0.1087	0.00995	0.03237	-0.00438	-0.438
GT Small Business	0.062	-0.10725	0.00995	0.02917	-0.00613	-0.613

Appendix B

Electricity rates in South Carolina

The average electricity price for residential customers in the State is 12.27 cents per kWh (EIA, 2019). The actual charges that residential customers pay in South Carolina vary widely between utilities. For example, Duke Energy has a monthly basic facility charge of $11.78; a charge of 11.353 cents per kWh for the first 800 kWh and 10.35 cents per additional kWh (Duke Energy Progress, 2020). Dominion South Carolina has basic facility charge of $9; a charge of 11.602 cents per kWh for the first 800 kWh and 12.788 cents per additional kWh. Santee Cooper has a basic monthly charge of $19.50, and a kilowatt-hour charge of 11.97 for the summer seasons and 0.099 cents per kWh during non-summer seasons. Finally, each electric cooperative establishes its own rate schedule. As an example, Berkeley electric cooperative has a daily $0.99 Service Availability Fee ($29.7 monthly) and a charge of 11.82 cents per kWh (Berkeley Electric Cooperative, 2020)

Appendix C

Calculation of the NPV of emissions avoided by each alternative

Electricity generation emissions S.C			Cost per metric ton	
Sulfur dioxide	0.4	lbs/MWh		20000
Nitrogen oxide	0.3	lbs/MWh		4700
Carbon dioxide	639	lbs/MWh		12
Alternative 2				
Total MWh	935663			
Emissions avoided	lb	Metric tons		Avoided Costs
Sulfur dioxide	374265.2	169.764	$	3,395,281
Nitrogen oxide	280698.9	127.323	$	598,418
Carbon dioxide	5.98E+08	271198.1	$	3,254,377
NPV total costs avoided			$	7,248,076
Alternative 3 and 4				
Total MWh	247249			
Emissions avoided	lb	Metric tons		NPV Avoided Costs
Sulfur dioxide	98899.61	44.86016	$	897,203
Nitrogen oxide	74174.71	33.64512	$	158,132
Carbon dioxide	1.58E+08	71664.11	$	859,969
Total			$	1,915,305

REFERENCES

Barbose, G., Darghouth, N., Hoen, B., & Wiser, R. (2018). Income Trends of Residential PV Adopters: An analysis of household-level income estimates.

Berkeley Electric Cooperative. (2020). Understanding Your Bill | Berkeley Electric Cooperative. https://www.berkeleyelectric.coop/understanding-your-bill

Borenstein, S., & Davis, L. W. (2016). The Distributional Effects of US Clean Energy Tax Credits. 45.

Rulemaking 14-07-002, Alternate decision adopting alternatives to promote solar distributed generation in disadvantaged communities (2018). http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M216/K789/216789285.PDF

Resolution E-4999, (2019). http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M297/K211/297211380.PDF

California Public Utilities Commission. (2020). Green Tariff/Shared Renewables Program (GTSR). https://www.cpuc.ca.gov/General.aspx?id=12181

City of Charleston. (2015). Sea level rise strategy for Charleston South Carolina. https://www.charleston-sc.gov/DocumentCenter/View/10089/12_21_15_Sea-Level-Strategy_v2_reduce?bidId=

Clean Air Task Force. (2016). Toll from Coal. https://www.tollfromcoal.org/#/map/(title:none//detail:none//map:none/US)

Clean Energy States Alliance. (2019). Solar with JusticeStrategies for Powering Up Under-Resourced Communities and Growing an Inclusive Solar Market. https://cesa.org/assets/2019-Files/Solar-with-Justice.pdf

Coleman, K., Blank, T. K., Probst, C., & Waller, J. (2017). HOW THE SOLAR FINANCING INDUSTRY CAN MEET $16 BILLION IN INVESTMENT DEMAND BY 2020. 34.

Cook, J. J., & Shah, M. (2018a). Reducing Energy Burden with Solar: Colorado's Strategy and Roadmap for States (NREL/TP--6A20-70965, 1431421). https://doi.org/10.2172/1431421

Cook, J. J., & Shah, M. R. (2018b). Focusing the Sun: State Considerations for Designing Community Solar Policy (NREL/TP--6A20-70663, 1419711; p. NREL/TP--6A20-70663, 1419711). https://doi.org/10.2172/1419711

Dagher, L., Bird, L., & Heeter, J. (2017). Residential green power demand in the United States. Renewable Energy, 114, 1062-1068. https://doi.org/10.1016/j.renene.2017.07.111

Department o Regulatory Agencies. (2016, junio 29). PUC approves solar gardens settlement after rehearing. Department of Regulatory Agencies. https://www.colorado.gov/pacific/dora/news/puc-approves-solar-gardens-settlement-after-rehearing

Dobes, L., Leung, J., & Argyrous, G. (2016). Appendix 7: Deadweight economic loss caused by raising revenue for projects and programs. En Social cost-benefit analysis in Australia

and New Zealand (pp. 203-212). ANU Press; JSTOR. https://www.jstor.org/stable/j.ctt1d10hms.19

Dominon Energy. (2020). Compare Solar Programs | Solar For Your Home | For My Home | Dominion Energy South Carolina. https://www.sceg.com/for-my-home/solar-for-your-home/compare-solar-programs#community-solar

Drehobl, A., & Ross, L. (2016). How Energy Efficiency Can Improve Low Income and Underserved Communities. 56.

Duke Energy LLC. (2018). Joint application of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC to establish green source advantage programs and riders. https://dms.psc.sc.gov/Attachments/Matter/5ac5b03b-46f7-4859-b995-66393368e247

Duke Energy Progress. (2020). RESIDENTIAL SERVICESCHEDULE RES-59. https://www.duke-energy.com/_/media/pdfs/for-your-home/rates/electric-sc/r2scschedulertoud.pdf?la=en

EIA. (2018). Electricity prices are highest in Hawaii but expenditures are highest in South Carolina. https://www.eia.gov/todayinenergy/detail.php?id=34932

EIA. (2019). South Carolina Profile. https://www.eia.gov/state/print.php?sid=SC

EPA. (2016). What Climate Change Means for South Carolina. 2. https://doi.org/EPA 430-F-16-042

Eric Cody. (2019). The Case of Cherryland Electric Cooperative. Merican Electric Cooperatives.

Fox, E., Edwards, T. B., & Drory, M. D. (2018). South Carolina Solar Development—Tracking the Effects of Act 236 (2014-2017) (SRNL--STI-2018-00239, 1439435). https://doi.org/10.2172/1439435

Funkhouser, E., Blackburn, G., Magee, C., & Rai, V. (2015). Business model innovations for deploying distributed generation: The emerging landscape of community solar in the U.S. Energy Research & Social Science, 10, 90-101. https://doi.org/10.1016/j.erss.2015.07.004

Heeter, J. S., Bird, L. A., O'Shaughnessy, E. J., & Koebrich, S. (2018). Design and Implementation of Community Solar Programs for Low- and Moderate-Income Customers (NREL/TP--6A20-71652, 1488510). https://doi.org/10.2172/1488510

Hillary Dobos, & Emily Artale. (2017). Insights from the CEO Low-Income Community Solar Demonstration Project.pdf. https://www.colorado.gov/pacific/sites/default/files/Insights%20from%20the%20CEO%20Low-Income%20Community%20Solar%20Demonstration%20Project.pdf

House Bill 10-1342. (2010). https://leg.colorado.gov/sites/default/files/images/olls/2010a_sl_344.pdf

Intergovernmental Panel on Climate Change. (2014). Annex III Technology-specific Cost and Performance Parameters. Cambridge University Press. https://doi.org/10.1017/CBO9781107415416

Katharine McCormick,. (2015). Bridging the Clean Energy Divide: Affordable Clean Energy Solutions for Today and Tomorrow. The Natural Resources Defense Council.

https://www.nrdc.org/sites/default/files/clean-energy-benefits-vulnerable-comms-report.pdf
LEAD Tool. (s. f.). Energy.Gov. Recuperado 14 de abril de 2020, de https://www.energy.gov/eere/slsc/maps/lead-tool
Lotus Engineering and Sustainability LLC. (2015). Analysis of the fulfillment of the low-income carve-out for community solar subscriber organizations. https://www.colorado.gov/pacific/sites/default/files/atoms/files/Low-Income%20Community%20Solar%20Report-CEO.pdf
Marten, A. L., Kopits, E. A., Griffiths, C. W., Newbold, S. C., & Wolverton, A. (2015). Incremental CH4 and N2O mitigation benefits consistent with the US Government's SC-CO2 estimates. Climate Policy, 15(2), 272-298. https://doi.org/10.1080/14693062.2014.912981
Matek, B. (2016). An examination of voluntary green power programs at U.S. utilities using behavioral science principles. The Electricity Journal, 29(3), 55-63. https://doi.org/10.1016/j.tej.2016.03.011
Moezzi, M., Ingle, A., Lutzenhiser, L., & Sigrin, B. O. (2017). A Non-Modeling Exploration of Residential Solar Photovoltaic (PV) Adoption and Non-Adoption (NREL/SR--6A20-67727, 1379469). https://doi.org/10.2172/1379469
National Renewable Energy Laboratory. (2014). Community shared solar. Policy and regulatory considerations. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy14osti/62367.pdf
Nuclear Energy Institute. (s. f.). South Carolina and Nuclear Energy. Recuperado 7 de mayo de 2020, de https://www.nei.org/CorporateSite/media/filefolder/resources/fact-sheets/state-fact-sheets/South-Carolina-State-Fact-Sheet.pdf
O'Shaughnessy, E., Heeter, J., & Sauer, J. (2018). Status and Trends in the U.S. Voluntary Green Power Market (2017 Data). Renewable Energy, 60.
Pacific Gas and Electric Company. (2018). Establish and Implement the Disadvantaged Communities Green Tariff (DAC-GT) Program Rate and the Community Solar Green Tariff (CS-GT) Program Rate. https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_5362-E.pdf
Sherry Stou, Eliza Hotchki, & Nathan Lee. (2018). Distributed energy resources for climate resilience. National Renewable Eenergy Laboratory. https://www.nrel.gov/docs/fy18osti/71310.pdf
Shindell, D. T. (2015). The social cost of atmospheric release. Climatic Change, 130(2), 313-326. https://doi.org/10.1007/s10584-015-1343-0
Sigrin, B. O., & Mooney, M. E. (2018). Rooftop Solar Technical Potential for Low-to-Moderate Income Households in the United States (NREL/TP--6A20-70901, 1434891). https://doi.org/10.2172/1434891
Street, M., & Francisco, S. (2018). Discussion of South Carolina Act 236: Version 2.0. 127.

Thind, M. P. S., Tessum, C. W., Azevedo, I. L., & Marshall, J. D. (2019). Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography. Environmental Science & Technology, 53(23), 14010-14019. https://doi.org/10.1021/acs.est.9b02527

U.S Department of Energy. (2019). Weatherization Works (DOE/1561). https://www.energy.gov/sites/prod/files/2019/07/f64/WAP-Fact-Sheet-2019.pdf

US EPA, O. (2018, julio 26). Utility Green Tariffs [Overviews and Factsheets]. US EPA. https://www.epa.gov/greenpower/utility-green-tariffs

Vaishnav, P., Horner, N., & Azevedo, I. L. (2017). Was it worthwhile? Where have the benefits of rooftop solar photovoltaic generation exceeded the cost? Environmental Research Letters, 12(9), 094015. https://doi.org/10.1088/1748-9326/aa815e

Wanderscheid, D., Environmental, B., Raker, J., & Burns, L. (2010). A guide to community solar. 56.

Xcel Energy. (2017). 2016 Renewable Energy Standard Compliance Report. https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/CO-RES-Compliance-Report-2016%20.pdf