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Improving Residential Energy Efficiency in the City of Charlottesville

APPLIED POLICY PROJECT

Prepared for the Community Climate Collaborative

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CLIENT PROFILE

The Community Climate Collaborative (C3), formerly known as the Charlottesville Climate Collaborative, is a 501(c)3 non-profit committed to advancing policies and programs that address the challenges of climate change. C3's mission is to catalyze "climate action at the community level through collaboration, program, and advocacy which directly reduce climate pollution and elevate the climate leadership of Virginia communities" (C3, 2020). C3 engages with community stakeholders through residential, commercial, and equity-focused programs.

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, by the University of Virginia, or by any other agency.

HONOR PLEDGE

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

TABLE OF CONTENTS

ACRONYMS AND DEFINITIONS

AMI – Area Median Income

BCA – Benefit-Cost Analysis

C3 – Community Climate Collaborative

DOE – United States Department of Energy

EEM – Energy Efficiency Mortgage

EIA – Energy Information Agency

EPA – United States Environmental Protection Agency

HUD – United States Department of Housing and Urban Development

IPCC – Intergovernmental Panel on Climate Change

LEAP – Local Energy Alliance Program

LLR – Loan Loss Reserve

NPV – Net Present Value

NREL – National Renewable Energy Laboratory

OBF – On-Bill Financing

PACE – Property Assessed Clean Energy

RGGI – Regional Greenhouse Gas Initiative

RLF – Revolving Loan Fund

UVA CCU – University of Virginia Community Credit Union

Energy efficiency refers to using less energy to perform the same task or service. Energy efficient upgrades eliminate wasteful energy consumption.

Cost burden refers to the share of household income spent on a given good or service, and is commonly used to describe household expenditures on housing and energy.

EXECUTIVE SUMMARY

Residential energy usage in the City of Charlottesville is inefficient. Nearly 30 percent of Charlottesville's greenhouse gas emissions come from residential energy consumption, and without intervention, Charlottesville is unlikely to achieve its goal of reducing greenhouse gas emissions 45 percent by 2030 (City of Charlottesville, 2020a).

Improving residential energy efficiency can reduce Charlottesville's greenhouse gas emissions while lowering residents' energy costs over time. However, the upfront cost of energy efficiency upgrades is too high for more than one-third of households in the City of Charlottesville to afford. As electricity prices rise under Virginia's forthcoming carbon dioxide cap-and-trade program, lower-income and capital constrained households that are unable to invest in efficiency upgrades will face increasing electricity bills and energy burdens.

C3 has a unique opportunity to propose a residential efficiency financing program for implementation in Charlottesville that aims to enhance the affordability and accessibility of energy efficiency upgrades for low-income and otherwise cost-burdened households. This analysis investigates several policy alternatives and evaluates them according to the criteria of *benefit-cost analysis, equity, and feasibility.* The alternatives are as follows:

Alternative 1: Let Present Trends Continue

Alternative 2: On-Bill Financing

Alternative 3: Revolving Loan Fund

Alternative 4: Loan Loss Reserve

This analysis recommends Alternative 2: On-Bill Financing. The program would require Charlottesville Gas to cover the upfront cost of energy efficiency upgrades and allow customers to pay back the investment over time on their gas bill while enjoying energy savings. This policy alternative would most equitably improve Charlottesville's residential energy efficiency and ensure that households that would otherwise be unable to afford upgrades gain access to the financing program.

PROBLEM STATEMENT

The upfront cost of investing in residential energy efficiency upgrades is too high for more than one-third of households in the City of Charlottesville to afford. Without intervention, Charlottesville's low-income and cost-burdened households will continue to inefficiently use energy. The prohibitively high upfront cost of residential energy efficiency upgrades will lead an already disadvantaged population to become worse off as electricity prices rise and ultimately prevent Charlottesville from meeting its goal of reducing greenhouse gas emissions 45 percent by 2030 (City of Charlottesville, 2020a).

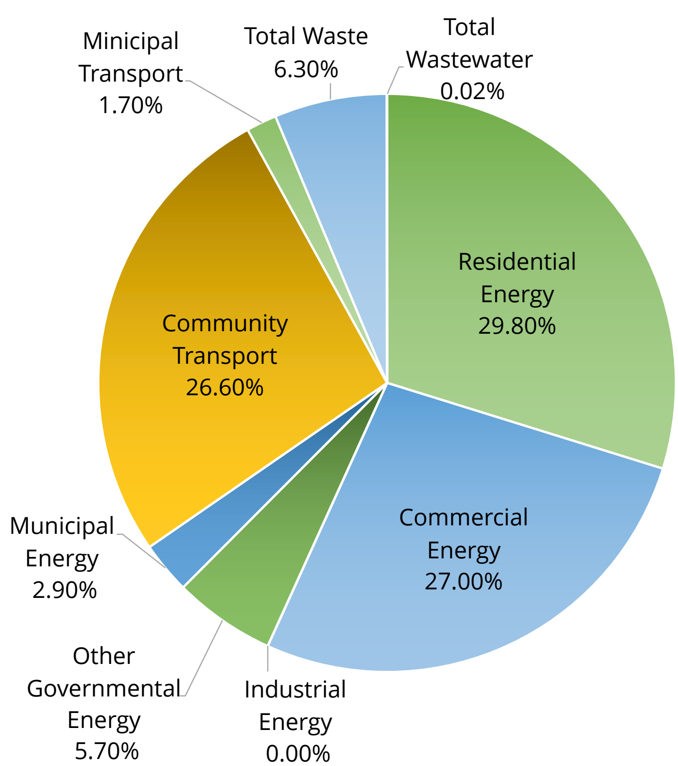
BACKGROUND

CHARLOTTESVILLE'S GREENHOUSE GAS EMISSIONS

On July 1st, 2019, the Charlottesville City Council established its goal of reducing community-wide greenhouse gas emissions 45 percent by 2030 from its 2011 inventory year and achieving carbon neutrality by 2050 (City of Charlottesville, 2020a). This goal was designed to respond to the challenges of climate change, a global problem driven by anthropogenic greenhouse gas emissions. By emitting greenhouse gases and contributing to global climate change, fossil fuel (i.e., coal, oil, and natural gas) production and consumption imposes a negative externality on society as a whole (Hafstead, 2019). As it stands, the market price of fossil fuels does not fully reflect its total cost to society, meaning that fossil fuels are underpriced and overconsumed relative to the socially optimal level (Gerarden et al., 2015).

When fossil fuels are burned, they emit greenhouse gases, including carbon dioxide, methane, nitrous oxide, and more. Released to the atmosphere, these greenhouse gases absorb radiation from the sun and prevent heat from escaping, causing the global climate to warm over time (Shaftel, 2020). As outlined in the 2015 Paris Agreement, climate change is projected to have severe impacts on humans and the environment if the international community fails to decrease its greenhouse gas emissions and limit warming above 2°C. These impacts encompass devastating ramifications from sea level rise and ocean acidification to intensified natural disasters, with disproportionate effects on vulnerable subpopulations that have fewer resources to use for adaptation efforts (IPCC, 2018).

Figure 1. Charlottesville Greenhouse Gas Emissions by Sector in 2016
(City of Charlottesville, 2019a)



Greenhouse gas-emitting fossil fuels are burned for electricity, heating, and other residential energy needs. In the United States, residential energy use comprises more than 20 percent of the nation's total energy consumption; in Charlottesville, it accounts for 47 percent of total energy consumption. This disparity in energy consumption is largely attributable to the small size of Charlottesville's industrial sector, since this sector accounts for the greatest share of energy consumption at the national level (U.S. Environmental Protection Agency (EPA), 2018; City of Charlottesville, 2019a; EIA, 2019).

Residential energy consumption generates 29.8 percent of Charlottesville's community-wide greenhouse gas emissions, which is more than the city's commercial and industrial emissions combined (see Figure 1; City of Charlottesville, 2019a). As the single largest source of community-wide greenhouse gas emissions, Charlottesville's residential energy use must be reduced in order to meet the city's goal of reducing emissions 45 percent by 2030 (City of Charlottesville, 2020a).

VIRGINIA'S RECENT CLIMATE POLICY CHANGES

The Virginia General Assembly recently passed the Clean Energy and Community Flood Preparedness Act, and Governor Ralph Northam has stated that he looks forward to signing the Act into law soon (Northam, 2020). This policy instructs Virginia to establish a carbon dioxide cap-and-trade program that complies with Regional Greenhouse Gas Initiative (RGGI) standards, allowing for Virginia to join RGGI as a full participant in the near future (SB 1027, 2020). RGGI is a cap-and-trade program that sets a regional limit on the amount of carbon dioxide emissions that electric power plants can emit and requires power producers to purchase tradeable emissions permits, sometimes referred to as allowances (Ceres, 2020; RGGI, 2020). Purchasing tradeable emissions permits forces fossil fuel and power producers to pay for the social cost of their greenhouse gas emissions, thereby encouraging them to reduce production and substitute cleaner energy production techniques over time (Hafstead, 2019).

In the short term, Virginia's power producers are likely to shift the burden of increased production costs onto consumers in the form of higher electricity prices. Although other environmental policies like the recently enacted Virginia Clean Economy Act include measures that add considerable uncertainty to this assertion, few researchers have credibly modeled how future electricity prices will change in response to these policies. That said, this analysis anticipates that electricity prices will rise as the RGGI cap on emissions declines and Virginia increases investments in renewable energy (RGGI, 2020; Greenstone & Nath, 2019; Miller, 2017).

Virginia's cap-and-trade program will help Charlottesville reach its 2030 greenhouse gas emissions reduction goal, as many consumers will reduce their energy use in response to higher prices. Households that can afford energy efficiency upgrades or renewable energy installations will face a greater incentive to invest in energy efficiency, while households that cannot afford upgrades will experience a reduction in welfare, forced to pay more to maintain their energy usage or reduce their usage in favor of other needs.

In anticipation of the Clean Energy and Community Flood Preparedness Act's potential to adversely impact low-income households with the carbon dioxide cap-and-trade program it creates, the policy dedicates 50 percent of the revenues from emissions permit sales to energy efficiency programs for low-income families (SB 1027, 2020; Southern Environmental Law Center, 2020). However, the Charlottesville community is unlikely to be targeted with low-income energy efficiency programs, as it has a higher area median income (AMI) than many other communities in Virginia (Hays, 2020). For Charlottesville residents, this means that energy efficiency upgrades will be both increasingly desirable and unaffordable.[1]

THE AFFORDABLE HOUSING CRISIS

Affordable housing is underprovided by private markets across the United States. According to the U.S. Department of Housing and Urban Development (HUD), families that spend more than 30 percent of their annual income on housing are considered cost-burdened and in need of affordable housing assistance (HUD, 2019). In 2014, nearly 40 million households in the United States were cost-burdened, equal to 12 percent of the nation's population (EPA, 2018). Housing cost burdens limit the amount of income families have to spend on other necessities, including food, clothing, education, and healthcare (McGowan, 2019).

Charlottesville's affordable housing crisis is even more severe. In 2015, more than one-third of all families in the City of Charlottesville were cost-burdened by housing; among homeowners, 25 percent were cost-burdened, and among renters, 47 percent were cost-burdened (City of Charlottesville, 2017). Although the Charlottesville Redevelopment and Housing Authority offers public housing and vouchers to households in need of affordable housing, there are currently 1,651 households on the eight-year waitlist to access these options. The number of affordable housing units in Charlottesville must double over the next 20 years in order to meet future needs (Kralik, 2018; Robert Charles Lesser & Co. Real Estate Advisors, 2016).

Although some cost-burdened households are moderate-to-high-income, more than 80 percent of cost-burdened households in Charlottesville and Albemarle earn less than or equal to 80 percent of the AMI – $89,600 as of 2018 – each year, thereby classifying them as low-income according to HUD (HUD, 2019). Among extremely low-income households – those earning 30 percent or less of the AMI – more than 70 percent are cost-burdened (Hays, 2020). Because cost-burdened households are already spending more than 30 percent of their income on housing-related expenses and more than 80 percent of them

[1] A quantitative analysis of this policy's effects that accounts for the uncertainty in future electricity prices is included in the section Alternative 1: Let Present Trends Continue.

are also low-income, this analysis assumes that cost-burdened households in the City of Charlottesville are unable to afford the upfront cost of energy efficiency upgrades.

Many of the factors driving Charlottesville's affordable housing crisis – including rising construction costs, prohibitive zoning regulations, and low wages – fall outside the scope of this analysis (Stout, 2019). Rather, this analysis will focus on cost burdens that households face related to energy and utility costs. On average, households across the U.S. spend 3.5 percent of their total income on energy costs; by contrast, low-income urban households across the nation spend 7 percent of their annual income on energy costs (EPA, 2018). This disparity exists because the percentage of income that goes towards energy bills decreases as income increases, and because low-income housing units are more likely to have outdated equipment and poor housing conditions (EPA, 2018). As climate change intensifies and the number of extreme hot and cold days each year increases, experts project that low-income households will be subject to even greater energy cost burdens (Habel, 2019).

THE ENERGY EFFICIENCY GAP

It may be possible to mitigate this trend of rising energy cost burdens if residents make energy efficiency upgrades and reduce their reliance on fossil fuels. According to the American Council for an Energy-Efficient Economy, about 35 percent of the energy cost burden experienced by low-income households could be eliminated if energy efficiency improvements were made to bring low-income housing up to the efficiency level of the average U.S. home (ACEEE, 2016). Similarly, the U.S. Department of Energy estimates that homeowners can save $200 to $400 per year on their energy bills by making energy efficiency upgrades, including sealing air leaks and upgrading air conditioning equipment (EPA, 2018). Clearly, there is great potential to fill this so-called energy efficiency gap in a cost-effective manner, and the EPA recommends that local governments simultaneously tackle the affordable housing crisis and reduce residential greenhouse gas emissions by designing energy efficiency programs for affordable housing and low-income populations (see Box 1; EPA, 2018; Jaffe & Stavins, 1994).

Several barriers can prevent energy efficiency programs for low-income families from effectively reducing cost burdens, thereby allowing the energy efficiency gap to persist (Gerarden et al., 2015). For one, the upfront cost of energy efficiency upgrades is prohibitively high for the one-third of households in Charlottesville that are already burdened by housing costs. Whereas higher-income households can afford to make energy efficiency improvements and reap cost savings over time, lower-income households generally lack the capital necessary to do so (EPA, 2018). Rebates and partial loans may be insufficient in encouraging households to install efficiency upgrades because they require households to bear some or all of the upfront cost.

Credit constraints also limit the effectiveness of energy efficiency programs. On average, lower-income households in the United States have lower credit scores than higher-income households (Beer et al., 2018). Lenders are wary of lending to borrowers with low credit scores; borrowers with poor credit are perceived as riskier than borrowers with good credit because they may be more likely to default on a loan and impose a loss on the lender (Gillingham & Palmer, 2014). In the energy efficiency market, borrowers may have more information about their potential for energy savings and their risk of default than lenders. Even though a low-income household may in fact be unlikely to default on a loan because of the large energy savings it would reap from energy efficiency upgrades, it is impossible for a lender to identify this household's potential for high payoff if it uses credit scores as its decision tool. This information asymmetry results in credit rationing, wherein lenders are unwilling to supply funding to interested borrowers, thereby further constraining lower-income households' access to credit and energy efficiency financing (Gillingham & Palmer, 2014; Palmer et al., 2012).

Box 1. Spotlight on Park's Edge

The Park's Edge housing community in Charlottesville offers affordable housing to lower-income residents. In 2004, the owners began major renovations including the installation of dishwashers, central air conditioning, and washing machines using the Low-Income Housing Tax Credit. These upgrades increased residents' energy bills, so the owners of Park's Edge subsequently invested in energy efficiency upgrades through a partnership with the Local Energy Alliance Program (LEAP) in 2005 to reduce their residents' expenses.

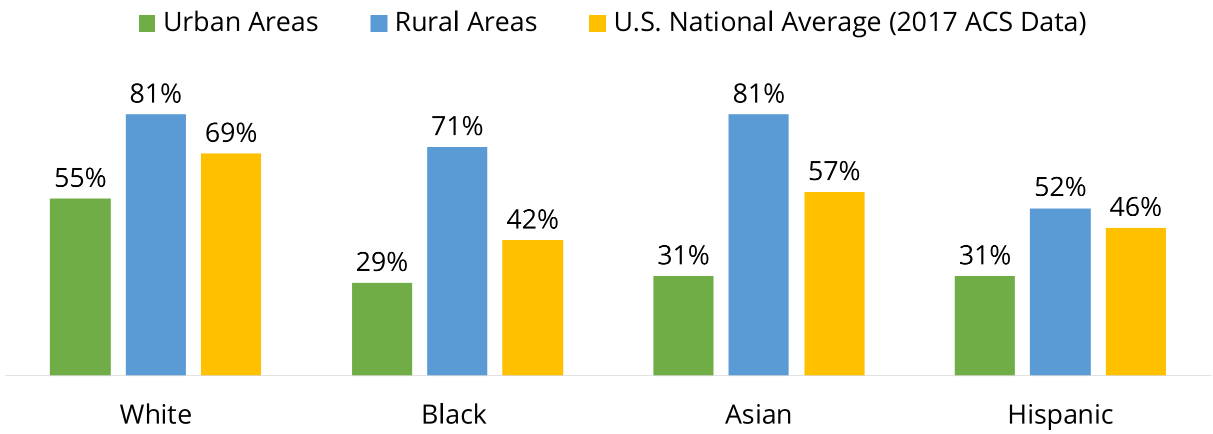
For Crystal Barbour and her two kids, the energy efficiency upgrades led to a 50 percent decrease in monthly energy bills, thereby improving their quality of life. "When bills were higher, I had to choose between paying the bill and something else," said Crystal. "Sometimes it was groceries. You would just eat cheap when it was electric bill week" (Virginia Multifamily Energy Efficiency Coalition, 2018).

Image source: Hays, 2018

This barrier is further complicated by the racial gap in access to credit. From 2007 to 2009, White households in the Thomas Jefferson Region, which includes the City of Charlottesville, were 10 percent more likely to be approved for a mortgage application than Black applicants with the same level of income. Historically, Black and Hispanic households have also faced discrimination in the rental and homebuying markets, suggesting that energy efficiency programs for low-income families involving loans or mortgages may disproportionately benefit White households in Charlottesville (Thomas Jefferson HOME Consortium & City of Charlottesville, 2011).

Furthermore, low-income renters have little agency in making energy efficiency upgrades; this issue is particularly pronounced due to the split incentive that exists between landlords and renters. When renters pay for energy and utilities, landlords have no obvious incentive to make energy efficiency upgrades, as they will not be directly rewarded with energy cost savings over time (EPA, 2018). Again, this challenge more severely affects non-White families, as Black, Asian, and Hispanic families in Charlottesville are less likely to own their homes and accordingly more likely to rent from landlords. In 2017, 55 percent of White households in the Charlottesville area owned their homes, while approximately 30 percent of Black, Asian, and Hispanic families owned their homes (see Figure 2; Central Virginia Regional Housing Partnership, 2019).

Figure 2. Homeownership Rates by Race in the Charlottesville Area (CVRHP, 2019)



An additional reason for the energy efficiency gap's persistence is consumer uncertainty and knowledge gaps surrounding the energy savings potential of energy efficiency upgrades (Gerarden et al., 2015). Some Charlottesville residents may not have any knowledge about how or why energy efficiency upgrades help them save, and they may be distrustful of private companies who advertise energy efficiency programs to them. Others may not be confident in the potential of energy efficiency upgrades to generate cost savings due to uncertain future energy prices (Gillingham & Palmer, 2014; Palmer et al., 2012).

The aforementioned barriers justify government intervention to design an energy efficiency financing program that enhances the affordability and accessibility of energy efficiency upgrades in order to improve the welfare of Charlottesville's cost-burdened households and reduce residential greenhouse gas emissions.

LITERATURE REVIEW

CHARLOTTESVILLE'S EXISTING ENERGY EFFICIENCY PROGRAMS

In 2010, the City of Charlottesville implemented the Reduced Interest Rate PowerSaver Loan program in partnership with LEAP and the University of Virginia Community Credit Union (UVA CCU) to offer low-interest loans for residential energy efficiency upgrades. The program allowed residents to buy the loan down to a 0 percent annual percentage rate, meaning that Charlottesville residents could take out loans to make improvements ranging from water heater replacements to solar panel installations with 0 percent interest. In its first three years of implementation, the program made more than 150 PowerSaver loans. However, the program is currently unavailable due to funding limitations, and the nationwide PowerSaver Loan program underlying the city's initiative has faced challenges in reaching its desired level of participation (Block et al., 2014; City of Charlottesville, 2020b; LEAP, 2011).

The city currently offers a one-year 50 percent reduced tax rate for energy efficient buildings, as well as five-year tax credits for households that purchase and install solar panels. Further, the city offers cash rebates for households that install low-flush toilets, rain barrels, tankless water heaters, and programmable thermostats (City of Charlottesville, 2020b). While program evaluations indicate that these types of "traditional" financing options can reduce household energy use – with rebates reducing household energy usage by as much as 5 percent – they do little to address the high upfront cost associated with many whole-house efficiency improvements (Michigan Saves, 2017; Alberini & Towe, 2015; Borgeson et al., 2014; Zimring et al., 2013; Fuller et al., 2009; IEA, 2008; Jaffe & Stavins, 1994). In other words, with the suspension of Charlottesville's Reduced Interest Rate PowerSaver Loan program, the city is in search of financing mechanisms to reduce the high upfront cost of residential energy efficiency upgrades with the goal of increasing the affordability and accessibility of upgrades for lower-income households.

PRIVATE VS. PUBLIC FINANCING MECHANISMS

Although private financial markets serve some consumers who wish to implement energy efficiency upgrades, a growing body of research indicates that moderate-to-low-income households and tenants of affordable multifamily properties are not well-served by private markets (Bell et al., 2013; Zimring et al., 2013). For example, most energy efficiency mortgage (EEM) programs are provided by private banks; from the 1990s until the 2008 housing market crash, a lack of access to mortgage credit, partly due to consumers' low credit scores, substantially limited the benefits of EEM programs (Palmer et al., 2012).

Many homeowners are unwilling to refinance their mortgage through EEM programs because the debt on their existing mortgage already exceeds their income (Block et al., 2014). Further, the literature indicates that privately-provided EEM programs do not address the financial barriers of renters, who face both high upfront costs for efficiency improvements and issues with split incentives between landlords and renters (Block et al., 2014; Bird & Hernandez, 2012; Johnson et al., 2011). Namely, when tenants pay for energy and utilities, landlords have no obvious incentive to make energy efficiency upgrades because they will not be directly rewarded with energy cost savings over time (EPA, 2018).

Municipally-provided and public-private energy efficiency financing programs are now more common and widespread than private programs and are supported by many economists and policymakers because they help households overcome capital and credit constraints (Palmer et al., 2012). On the other hand, some believe that government involvement in the financing market is not beneficial, as it creates new institutions, adds transaction costs to lending programs, and "crowds out" private lending that may have taken place had the government not intervened. However, it is practically difficult to measure the extent to which this "crowding out" has occurred, as temporal and geographic differences make it challenging to find a reliable counterfactual scenario (Kim & Nguyen, 2019; Cox, 2016; Palmer et al., 2012; Vogel & Adams, 1997).

Regardless of this debate, the failure of private markets to achieve desired levels of energy efficiency – that is, the persistence of the energy efficiency gap – has led many governments and utilities to develop financing strategies aimed at reducing the upfront cost of upgrades over the last two decades, including Property Assessed Clean Energy (PACE), On-Bill Financing (OBF), credit enhancements, and direct lending (Mundaca & Kloke, 2018; Michigan Saves, 2017; Johnson et al., 2016; Kats et al., 2011).

Property Assessed Clean Energy

A common financing program implemented in localities across the United States is Property Assessed Clean Energy (PACE) financing, in which municipalities finance energy efficiency upgrades by adding a special property tax assessment or charge to an owner's property tax bill as a loan repayment mechanism (Deason et al., 2016; Zimring et al., 2013). In the past, PACE financing has been highly effective at achieving program participation and improving residential energy efficiency (Mundaca & Kloke, 2018; Ameli et al., 2017; Kirkpatrick & Bennear, 2014; St. Jean, 2010). For example, the Long Island Green Homes PACE program has achieved almost 75 percent energy efficiency retrofit follow-through among audit participants, a rate much higher than other financing programs (St. Jean, 2010).

As of 2016, more than 30 states, including Virginia, had passed legislation necessary to allow municipalities to establish PACE programs (Deason et al., 2016; St. Jean, 2010). However, after the Federal Housing Finance Agency objected to PACE programs' interference in the prioritization of federally-funded mortgages in 2010, PACE property tax charges were subordinated to first mortgages and other property debts (Mundaca & Kloke, 2018; Zimring et al., 2013; Bird & Hernandez, 2012; St. John, 2010). With secondary status, residential PACE loans have become substantially less likely to achieve successful implementation, leading many localities to initiate On-Bill Financing (OBF) programs as an alternative (Mundaca & Kloke, 2018).

On-Bill Financing

A wealth of literature highlights OBF programs as a viable financing mechanism for energy efficiency upgrades (EPA, 2018). OBF involves the repayment of energy efficiency loans through existing monthly utility bill payments, with energy savings from efficiency improvements that are greater than or equal to the household's loan payments (Durkay, 2016; Johnson et al., 2016; Andersen et al., 2015; Henderson, 2012).

Research indicates that fewer customers default on OBF loans, suggesting that the payment of loans through monthly utility bills may make customers more likely to make payments relative to other types of loans (Durkay, 2016; Johnson et al., 2016; Palmer et al., 2012; Bell et al., 2011). It is important to note that although these findings are not causal, behavioral studies support the notion that repaying loans through utility bills that households already routinely pay reduces default rates (SEE Action, 2014). Reduced default rates allow programs to offer lower interest rates, with many existing programs offering 0 percent interest, as well as longer loan terms, thereby increasing the number of loan-qualifying customers (SEE Action, 2014; Block et al., 2014; Kats et al., 2011).

Certain features of OBF programs may further increase their potential to improve the affordability and accessibility of energy efficiency upgrades. First, OBF programs that use utility bill payment history – rather than credit scores – provide financing access to households with lower credit scores (Andersen et al., 2015).[2] Since the outstanding OBF loan is considered a service charge rather than debt, this program design also protects customers' ability to access credit for other purposes (Mundaca & Kloke, 2018). Second, tariff-based OBF programs, which attach the energy efficiency loan to the property meter rather than the property owner, have been effective in reducing the split incentive between landlords and renters (Johnson et al., 2016).[3]

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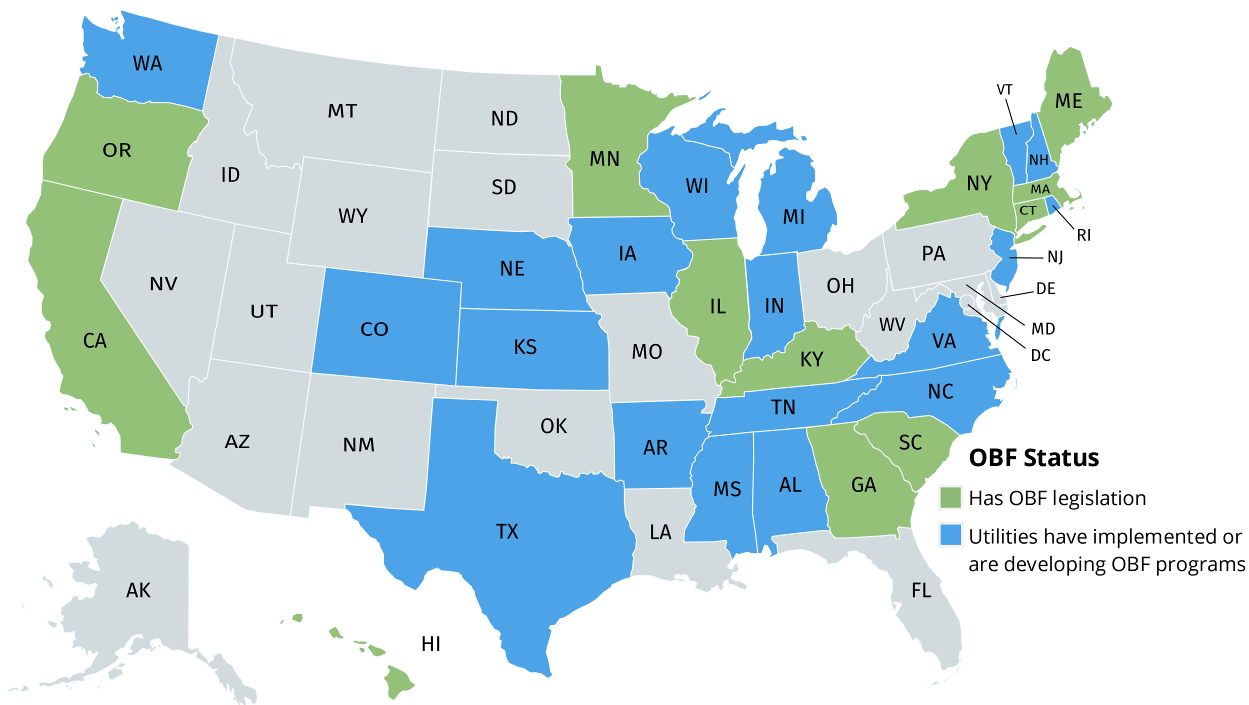
[2] The Holland Board of Public Works operates an OBF program in Michigan. The OBF program requires that households have 12 months of on-time bill payments to be eligible for participation (Porter, 2018).

[3] See Appendix A for a tariffed OBF case study of How$mart® and How$martKY™.

Although OBF programs have been implemented widely across the United States as seen in Figure 3, tariff-based OBF programs are a "newer innovation," and fewer program evaluations of this model are available in the literature (Mundaca & Kloke, 2018; Andersen et al., 2015; SEE Action, 2014). Thus far, evaluations of OBF programs indicate that program success is largely dependent on the willingness of utilities to provide energy efficiency services and take on the associated risk (Mundaca & Kloke, 2018; Kats et al., 2011).

Figure 3. OBF Implementation Across the United States (Andersen et al., 2015)



Credit Enhancements and Direct Lending

Many government and utility-operated residential energy efficiency financing programs leverage credit enhancements like Loan Loss Reserves (LLRs) and direct lending through Revolving Loan Funds (RLFs) to help private lenders increase the accessibility of offered loans. For instance, LLRs provide public funds to private lenders if borrowers default on their loans, reducing the risk taken on by private lenders and increasing their lending to households with lower credit scores, many of which may be moderate-to-low-income (Palmer et al., 2012). The literature indicates that credit enhancements attract private lenders and capital to energy efficiency markets, thereby supplementing government funds for efficiency-related loans (Andersen et al., 2015; Kats et al., 2011).

In contrast, RLFs offer direct loans to households for energy efficiency upgrades and are intended to be self-sustaining as households repay loans into the fund (Deason et al., 2016; Kats et al., 2011). By offering lower interest rates than private loans, RLFs help reduce the high upfront cost associated with efficiency improvements, although the speed with which they "revolve" may limit the number of loans allocated to riskier borrowers (Kats et al., 2011).

COMMON CHALLENGES AND BEST PRACTICES

Nearly all public and utility-operated financing programs have exhibited challenges with market penetration, reaching less than 1 percent to 5 percent of property owners eligible for a given program (Palmer et al., 2012). The failure of affordable financing options to penetrate the market and achieve high levels of consumer participation is largely attributable to low consumer demand for energy efficiency upgrades (Borgeson et al., 2014). Recently, many researchers and policy analysts have contended that the lack of demand for efficiency upgrades is the primary barrier to increasing residential energy efficiency, whereas the large body of research on financing mechanisms would suggest that a lack of access to capital and credit are mainly preventing efficiency improvements from taking place at a large scale (Mundaca & Kloke, 2018; Zimring et al., 2013).

Experts have not arrived at a clear consensus on this issue, and this policy analysis will principally focus on options to address the issue of the high upfront cost of upgrades in the City of Charlottesville. Given that behavioral biases, limited consumer demand, and informational barriers contribute to low levels of investment in energy efficiency upgrades, researchers agree that financing programs are most successful when complemented by other policy instruments or incentives (Mundaca & Kloke, 2018; Hayes et al., 2011). The literature indicates that offering low interest rates, bundling loans with rebates or tax credits, offering a relatively simple application process, using targeted marketing strategies, and investing time and training into program contractors – those who are actually installing the efficiency upgrades – increases the success of financing programs (Michigan Saves, 2017; Johnson et al., 2016).

LITIMATIONS AND RESEARCH GAPS

Most residential energy efficiency financing programs have been assessed qualitatively, with quantitative findings only pertaining to market penetration rates and program features (i.e., loan terms, interest rates, funding amounts, etc.) (Zimring et al., 2013; Cadmus Group, 2012). Additionally, the limited availability of data related to energy savings and market activity makes it challenging for policy analysis to comprehensively assess the success of various financing programs (Deason et al., 2016). That said, a wide body of research has found that engineering estimates of energy savings from efficiency upgrades overestimate actual energy savings because of consumers' behavioral response to improved energy efficiency (Fowlie et al., 2018; Gillingham et al., 2014). This "rebound effect" occurs when consumers increase their energy use in response to efficiency upgrades that make energy consumption more affordable (Fowlie et al., 2018). As a result, empirical analyses find that energy savings from efficiency upgrades are on the order of 5 to 40 percent lower than engineering estimates of energy savings (Gillingham et al., 2014).

Another important challenge is the voluntary nature of most energy efficiency financing programs. Without randomly assigned household participation, it is not possible to extract causal findings from studies of energy efficiency financing mechanisms, meaning that studies are quasi-experimental at best (Alberini & Towe, 2015; Palmer et al., 2012). Since most programs are voluntary, many households that choose to participate in municipal or utility-offered financing programs may have made efficiency upgrades anyway, implying that such programs are not necessarily making efficiency upgrades more accessible for moderate-to-low-income households.

One study with a regression discontinuity design supports this selection bias story: efficiency subsidies increased participation in a large-scale residential energy efficiency program, but the researchers found that 50 percent of all participants would have invested in efficiency upgrades even without the subsidy (Boomhower & Davis, 2014). This "additionality" concern suggests that policymakers must take care to ensure that financing programs reach consumers who would not be able to afford or access energy efficiency upgrades in the absence of public support (Allcott, 2016; Borgeson et al., 2014; Boomhower & Davis, 2014; Palmer et al., 2012).

TAKEAWAYS

Evaluations of financing programs for residential energy efficiency upgrades across the United States indicate that public and utility-operated programs including OBF, RLFs, and LLRs can successfully:

- Reduce the high upfront cost of efficiency upgrades
- Make upgrades more accessible for moderate-to-low-income households
- Fill the energy efficiency gap that exists in private markets (Deason et al., 2016; Andersen et al., 2015)

However, these financing programs do little to generate demand for efficiency upgrades, meaning that strategic marketing and the provision of multiple financing programs and incentives may be necessary to yield the city's desired level of residential energy efficiency (Mundaca & Kloke, 2018; Borgeson et al., 2014). Any financing program implemented in Charlottesville must be carefully designed to attract consumers and reach the one-third of households who are currently unable to afford energy efficiency upgrades (Allcott, 2016).

EVALUATIVE CRITERIA

The following criteria will be used to evaluate policy alternatives that aim to increase the affordability and accessibility of energy efficiency upgrades and reduce Charlottesville's residential greenhouse gas emissions, thereby aligning with C3's mission of catalyzing "climate action at the community level through collaboration, programs, and advocacy which directly reduce climate pollution" (C3, 2020).

BENEFIT-COST ANALYSIS

This quantitative criterion will project the benefits and costs of each alternative in terms of net present value (NPV) dollars over a 25-year time horizon using a 3.5 percent discount rate. The benefit-cost analysis (BCA) will value benefits and costs in monetary units, using market prices whenever possible and shadow prices for quantifiable benefits and costs that do not have market prices. A sensitivity analysis will be conducted to account for the impact of various assumptions (i.e., the discount rate, uncertainties in the baseline, etc.) on the outcome of the BCA. See Appendix B for BCA calculations.

This analysis will calculate the monetary value of each alternative as the present value of benefits less the costs, and the alternative with the **highest NPV** will be considered the most desirable on the BCA criterion. Policy alternatives will be assigned relative **scores ranging from 1-5,** and this criterion will have a **weight of 30%.**

Benefits will include:

- Energy savings for Charlottesville residents[4]
- Reduced healthcare costs resulting from a reduction in air pollution
- Comfort and quality-of-life improvements resulting from efficiency upgrades

Costs will include:

- Administrative costs borne by program operator(s) (i.e., labor, office space, etc.)
- Energy efficiency upgrade resource costs for participating households
- The opportunity cost of the program (i.e., the next best use of the city's funding)

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[4] All energy savings valuations used in this BCA account for the rebound effect. Note that the value of reduced greenhouse gas emissions is capitalized in household energy savings due to Virginia's forthcoming participation in RGGI, as energy prices will increase under the carbon dioxide emissions cap to reflect the social cost of carbon.

EQUITY

Consistent with C3's stated commitment to equity in climate action and the city's commitment to address equity in its Climate Action Plan, this qualitative criterion will assess the degree to which each alternative increases the affordability and accessibility of energy efficiency upgrades for low-income and cost-burdened households.

The propensity for each policy alternative to increase the affordability and accessibility of energy efficiency upgrades will be determined based on policy literature and case studies from other localities. This criterion will also consider the distribution of costs and benefits across stakeholders. Alternatives that allow low-income and cost-burdened households to receive the highest ratio of benefits to costs will be characterized as highly equitable in this analysis. This criterion will score policy alternatives as generating **high (5), medium (3), or low (1) equity,** and it will have a **weight of 40%.**

FEASIBILITY

This qualitative criterion will comprise political and administrative feasibility, which are fundamentally related in the work of C3 and the city government. Political feasibility will assess the likelihood that the city will implement a given policy proposal offered by C3, and will be determined by considering factors including:

- Stated views of city government officials
- Relevance to C3's mission
- Success of similar proposals in other localities

Administrative feasibility will examine the capacity of the city government and other stakeholders – including utility providers, landlords, and households – to manage and implement the policy alternatives. This aspect of the criterion will consider the need for capacity building and the long-term sustainability of an alternative upon implementation based on current features of the city government's operating model as described by official city documents and C3's contacts. Each alternative will be evaluated as having **high (5), medium (3), or low (1) feasibility,** and this criterion will have a **weight of 30%.**

POLICY ALTERNATIVES

The following policy alternatives are drawn from best practices in the energy efficiency financing literature and are intended to improve the affordability and accessibility of efficiency upgrades for low-income and cost-burdened households in Charlottesville:

Alternative 1: Let Present Trends Continue

Alternative 2: On-Bill Financing

Alternative 3: Revolving Loan Fund

Alternative 4: Loan Loss Reserve

COMMON FEATURES

Policy alternatives 2, 3, and 4 are similar in that they would involve C3 proposing an energy efficiency financing program to its contacts in the city government. All of the financing programs would require a program administrator to cover the upfront cost of efficiency upgrades and allow program participants to repay the administrator over time as they enjoy energy savings. Programs would use marketing strategies to target the low-income and cost-burdened households who comprise the one-third of Charlottesville residents who cannot afford efficiency upgrades due to capital and credit constraints.

In order to compare these policy alternatives and consider trade-offs according to the evaluative criteria, this analysis assumes the average upfront cost of efficiency upgrades is $8,000 per household, consistent with the market price of a cost-effective package of upgrades in Virginia and the average loan offered by residential energy efficiency lenders (EPA, 2019; Wilson et al., 2017; Hayes et al., 2011). Although the package of upgrades would vary between participants, a cost-effective package of upgrades could include the following measures, for example:

- High-efficiency heat pump installation
- Smart thermostat installation
- LED lighting installation
- Drill-and-fill wall cavity insulation
- Duct sealing and insulation (NREL, 2017a; Wilson et al., 2017)

Based on characteristics of existing residential financing programs, this analysis further assumes that each program would reach 100 new customers every year for 10 years, and participating households would have a maximum of 15 years to repay the program administrator for the upgrades (The Energy Efficiency Institute, Inc., 2016).

After installing a cost-effective package of efficiency upgrades, participating households can save a technically-estimated 4800 kWh of electricity per year on average, or about 34 percent of the average Virginia household's annual electricity consumption (Wilson et al., 2017; EIA, 2018). However, a participating household's real energy savings may be much lower than this technical estimate because of the rebound effect, housing stock characteristics, and weather fluctuations.

Empirical estimates indicate that average annual energy savings for low-income households may be as low as 1,371 kWh, or about 10 percent of the average Virginia household's electricity consumption (Gillingham et al., 2014; Drehobl & Castro-Alvarez, 2017; Hayes et al., 2011). This analysis estimates an average rebound effect of 20 percent of energy savings, and the uncertainty in household energy savings is further explored in the sensitivity analysis (see Appendix B; Gillingham et al., 2014). Furthermore, this analysis does not quantify natural gas savings separate from electricity savings, as the energy market is sufficiently competitive to assume that natural gas savings resulting from energy efficiency upgrades for households that use natural gas as the primary fuel source would be approximately equal to electricity savings for households that use electricity as the primary fuel source (NREL, 2017b; Avance, 2019; EIA, 2009).

KEY DIFFERENCES

Policy alternatives 2, 3, and 4 differ primarily in terms of the program administrators, participant eligibility criteria, and energy efficiency upgrade repayment features. These differences are explained in further detail in the following sections.

ALTERNATIVE 1: LET PRESENT TRENDS CONTINUE

C3 and the City of Charlottesville would let present trends continue without initiating a financing program for residential energy efficiency upgrades. Under present trends, the city would continue offering traditional financing options, including:

- A one-year 50 percent reduced tax rate for energy efficient buildings, including single and multifamily homes
- A five-year tax credit for households that purchase and install solar panels
- Cash rebates for households that install low-flush toilets, rain barrels, tankless water heaters, and programmable thermostats (City of Charlottesville, 2020b)

Apart from the city's offerings, C3 would continue to educate Charlottesville residents about the benefits of energy efficiency upgrades. C3 currently encourages households to install efficiency upgrades through its Home Energy Challenge. The Home Energy Challenge allows households to commit to and complete a variety of actions (i.e., wall insulation and efficient appliance installation) within 4-6 months of starting the program with guidance from C3 (C3, 2019). Thus far, the Challenge has successfully engaged with more than 370 homes and, under the assumption that the upgrades would not have happened otherwise, has prevented the release of almost 500 metric tons of carbon dioxide emissions (C3, 2019). This 500-metric-ton emissions reduction is a very small fraction of Charlottesville's annual residential greenhouse gas emissions, which totaled 107,857 metric tons of CO_2 equivalent in 2016 (City of Charlottesville, 2019a).

As described in the Background section of this report, Virginia will soon establish a cap-and-trade program consistent with RGGI standards to reduce the state's greenhouse gas emissions and accelerate progress towards a low-carbon economy (Northam, 2020). This policy will help the City of Charlottesville meet its greenhouse gas emissions reduction goal, as many consumers will reduce their energy consumption in response to higher electricity prices. Households that can afford efficiency upgrades will be more likely to invest in them, while cost-burdened and low-income households will experience a reduction in welfare, forced to pay more to maintain their current level of energy usage or reduce their usage in favor of other needs.

BENEFIT-COST ANALYSIS

This alternative will serve as the baseline for the BCA of the other three alternatives, with a score of 1. Key baseline trends include those of electricity prices and consumption in Virginia. Under present trends, residential electricity prices are projected to increase 3.2 percent each year according to a 2017 Joint

Legislative Audit and Review Commission analysis of Virginia's plan to participate in RGGI (Miller, 2017). Since the current residential electricity rate is 11.73 cents per kWh, this analysis projects a rate of 16.07 cents per kWh by 2030 and 25.78 cents per kWh by 2045 (EIA, 2018). However, this 3.2 percent annual increase estimate does not account for the effect of other recently passed environmental policies on electricity rates, and experts have yet to model future electricity rates in a manner that accounts for these recent policy changes. As a result, the sensitivity analysis in Appendix B accounts for the uncertainty associated with this figure and evaluates its effect on the NPV of the other policy alternatives.

As electricity rates rise, households will consume less electricity, on average; this analysis assumes a -0.4 price elasticity of electricity demand over the 25-year time horizon based on the findings of empirical meta-analyses (Deryugina et al., 2017; Burke & Abayasekara, 2017). The average Virginia household currently consumes 13,980 kWh of electricity per year, and under present trends, will decrease its annual consumption to 12,290 kWh by 2030 and 10,131 kWh by 2045 (EIA, 2018). Although this reduction in electricity consumption will help Charlottesville reach its goal of reducing greenhouse gas emissions 45 percent by 2030, this analysis does not aim to quantify or value emissions reductions because statewide climate policies will supersede Charlottesville's efforts and theoretically result in 100 percent carbon-free electricity generation by 2050 (Northam, 2020).

EQUITY

This policy alternative performs poorly with regard to the equity criterion and receives a rating of low with a score of 1. Rising electricity rates will disproportionately affect cost-burdened and low-income households who do not receive the benefits of energy efficiency programs funded by Virginia's cap-and-trade emissions permits sales (Schneider, 2020). Households that are unable to afford past levels of electricity consumption will be forced either to further reduce their usage and sacrifice their comfort or to ignore other needs (i.e., food, medical expenses, etc.) in favor of paying their electricity bills. Without access to capital or credit, low-income and historically marginalized households will experience a reduction in welfare under present trends.

FEASIBILITY

This alternative performs well with regard to the feasibility criterion and receives a rating of medium-high with a score of 4. Neither C3 nor the city government would bear any additional administrative costs under present trends. Although this alternative would be administratively feasible, the views of key stakeholders – including C3, the city government, and Charlottesville residents –

may limit the political feasibility of this alternative. Specifically, the city's Climate Action Plan must include strategies that address "effective funding programs and models for increased residential energy performance" (City of Charlottesville, 2020a). Both C3 and the city government have expressed interest in financing energy efficiency improvements, meaning that this alternative would not align with C3's mission or the city government's objectives. Further, Charlottesville residents may object to the city's inaction as their electricity bills begin to rise (Schneider, 2020). That said, the city's response to the coronavirus (COVID-19) pandemic is likely to prioritize spending on public health initiatives rather than energy efficiency initiatives, thereby enhancing the political feasibility of present trends (City of Charlottesville, 2020c).

OUTCOMES

	Benefit-Cost Analysis	Equity	Feasibility
Alternative 1: Let Present Trends Continue	**1** **Baseline** from 2020-2045	**1** **Low** Rising electricity prices will reduce welfare of low-income households	**4** **Medium-High** High administrative feasibility, medium political feasibility

ALTERNATIVE 2: ON-BILL FINANCING

With this alternative, C3 would propose that the City of Charlottesville initiate an On-Bill Financing (OBF) program through its municipal utility, Charlottesville Gas, which serves about 19,000 households in the Charlottesville area (City of Charlottesville, 2020d).[5] The OBF program would require Charlottesville Gas to incur the upfront cost of residential energy efficiency upgrades using $8 million in allocated funds from the city government. The allocated funds would be enough to cover upgrades with an average cost of $8,000 for 1,000 households over a period of 10 years.

Charlottesville Gas would target low-income and cost-burdened households with this program, and would use a household's utility bill payment history when determining whether to approve an applicant for OBF program participation. Approved households would then coordinate with private contractors to install energy efficiency upgrades using the funding offered by Charlottesville Gas. The program would allow households to repay the investment over a maximum term of 15 years at 0 percent interest on their existing monthly utility bill, with energy savings from efficiency improvements that are intended to be greater than or equal to the household's payments according to the principle of bill neutrality demonstrated by other OBF programs (DOE, 2019a; Durkay, 2016; Johnson et al., 2016; Andersen et al., 2015; Henderson, 2012).

Consistent with tariffed OBF programs across the United States, the energy efficiency investment and repayment responsibilities would be attached to the property meter rather than the original program participant to allow for the transfer of liability if the original participant were to move out of their residence (Mundaca & Kloke, 2018). By attaching the investment to the property meter and using utility bill payment history as the participant eligibility criterion, this program would structure energy efficiency financing as a service rather than a loan.

BENEFIT-COST ANALYSIS

This alternative passes the BCA with NPV $7,824,304 and a score of 5. The benefits of the OBF program include energy savings and improved comfort for the 1,000 households that install energy efficiency upgrades, as well as healthcare savings for the Charlottesville community as a result of reduced air pollution. The total present value of benefits is $17,134,141.

[5] Although Charlottesville Gas provides natural gas services to Charlottesville residents, the OBF program can function through the gas utility while encouraging electricity savings. Participating customers would pay on their monthly gas bill and see savings on their electricity bill. The calculation of energy savings used by Charlottesville Gas to determine monthly payment requirements would consider both electricity and natural gas savings, if any.

The costs of this alternative include the resource cost of efficiency upgrades, the opportunity cost of government spending, and the administrative costs incurred by Charlottesville Gas (i.e., program marketing, labor, and office space). The total present value of costs for the program is $9,309,837. See Appendix B for more.

EQUITY

This policy alternative performs well with regard to the equity criterion and receives a rating of high with a score of 5. This policy alternative directly targets the issue of credit rationing by using bill payment history as the eligibility criterion. Since low-income households have lower credit scores on average, using utility bill payment history rather than credit scores to determine program eligibility increases low-income households' access to energy efficiency financing (Beer et al., 2018; Gillingham & Palmer, 2014; Palmer et al., 2012). Although households with lower credit scores may also be more likely to have missed utility bill payments in the past, utility bill payment history does not factor into credit scores, meaning that households with poor credit but good utility bill payment history would be able to participate in the OBF program (Meni, 2016). Furthermore, this program design allows households to avoid paying upfront costs, incurring additional debt, or undergoing a credit check, all of which could otherwise impact a households' ability to access credit for other reasons (Mundaca & Kloke, 2018).

This alternative is also highly equitable in its distribution of benefits to renters and homeowners. Participating homeowners will accrue capital gains from increasing property values, and renters will be able to reap energy savings from this program because it reduces the split incentive between renters and landlords (Gillingham & Palmer, 2014; Bell et al., 2011). In other words, this OBF program allows Charlottesville Gas, rather than landlords, to cover the upfront cost of efficiency upgrades and then shifts the responsibility of payment to renters as they benefit from energy savings (Mundaca & Kloke, 2018).[6] Landlords may also accrue capital gains from increasing property values if their renters participate in the program. In addition, attaching the investment to the property meter rather than the applicant makes energy efficiency loans more accessible to renters who do not have plans for long-term residence and passes on the benefit of energy savings to future renters if current renters move out (Johnson et al., 2016).

The costs of this alternative primarily fall on Charlottesville Gas, and any costs passed onto consumers are likely to be evenly distributed among Charlottesville residents. The benefits of this alternative would largely accrue to those who are

[6] Charlottesville Gas would use allocated funds from the city government, which come from taxpayer revenues.

most likely to experience a reduction in welfare in the absence of energy efficiency financing. On balance, this analysis finds the OBF proposal highly equitable.

FEASIBILITY

This alternative performs poorly with regard to the feasibility criterion and receives a rating of low-medium with a score of 2. Both the city government and Charlottesville Gas are unfamiliar with OBF program development and management, meaning that this alternative would require significant capacity building for Charlottesville Gas prior to implementation. The administrative costs of this program may be greater than Charlottesville Gas is willing to bear, especially considering that it is currently sponsoring a free weatherization pilot program in partnership with LEAP (City of Charlottesville, 2019d). Although Charlottesville Gas's sponsorship of this pilot program indicates that it is willing to partner on some energy efficiency initiatives, Charlottesville Gas may not be willing to act as the sole operator of an OBF program. Absent the utility's strong commitment, evidence suggests that the program's cost-effectiveness and overall level of success is likely to be limited (Mundaca & Kloke, 2018).

On the other hand, developing an OBF program aligns with C3's mission and the city's objectives, particularly due to the success of similar programs in other localities (Fine et al., 2013; Bell et al., 2011). The political feasibility of this option may be further enhanced by the position of Charlottesville residents, who are likely to approve of this alternative because it is highly equitable and involves fewer transaction costs for consumers than other financing programs (Mundaca & Kloke, 2018). However, spending on efficiency programs may become less politically feasible as public health initiatives related to COVID-19 are prioritized over energy efficiency programs (City of Charlottesville, 2020c).

OUTCOMES

	Benefit-Cost Analysis	Equity	Feasibility
Alternative 2: On-Bill Financing	**5** **NPV $7,824,304** from 2020-2045	**5** **High** Reduces credit rationing, enhances affordability, and reaches renters	**2** **Low-Medium** Low administrative feasibility, medium political feasibility

ALTERNATIVE 3: REVOLVING LOAN FUND

This alternative would require C3 to develop a proposal for the City of Charlottesville to establish a Revolving Loan Fund (RLF) to provide households with greater access to direct loans for energy efficiency upgrades (DOE, 2019a). The RLF would be created through the reallocation of $8 million of city funds, enough to offer 1,000 households $8,000 energy efficiency loans over a 10-year period.

The city government would operate the RLF lending program, and would determine a household's eligibility for the program based on its credit score and any other relevant factors. The city's risk portfolio would be structured to allow for a share of loans to go to applicants with lower credit scores, thereby enabling this program to better reach the target population of low-income and cost-burdened residents in Charlottesville.[7] Upon approval, households would be able to use the loan to make efficiency upgrades on their own or through private contractors.

Approved households would then make monthly loan payments through a new portal in the city's online bill pay system at 0 percent interest over a maximum of 15 years, and their payments would flow back into the RLF to make it self-sustaining (Deason et al., 2016; Palmer et al., 2012; Kats et al., 2011). Although the program would have an initial reach of only 1,000 households, the program could reach additional households in the future as the RLF gets replenished by loan payments.

BENEFIT-COST ANALYSIS

This alternative passes the BCA with NPV $7,754,859 and a score of 4. The benefits of the RLF program include energy savings and improved comfort for the 1,000 households that install energy efficiency upgrades, as well as healthcare savings for the Charlottesville community as a result of reduced air pollution. The total present value of benefits is $17,134,141.

The costs of this alternative include the resource cost of efficiency upgrades, the opportunity cost of government spending, the administrative costs incurred by the city government (i.e., program marketing, labor, and office space), and the transaction costs (i.e., bill payments) incurred by participating households.[8] The present value of costs for the program is $9,379,282. See Appendix B for more.

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[7] The precise share of loans would be determined based on an internal assessment of risk versus equity.

[8] The key difference between the BCA of OBF and RLF is the transaction costs incurred through the RLF program by participating households that have to pay an additional monthly bill.

EQUITY

This policy alternative performs moderately well with regard to the equity criterion and receives a rating of medium with a score of 3. This alternative is designed to be affordable for eligible cost-burdened and low-to-moderate income households. By offering 0 percent interest rates and 15-year loan terms, the RLF program will allow consumers to spread out their payments over time as they enjoy energy savings. Thus, if properly targeted to reach households that would have otherwise been unable to afford efficiency upgrades, this alternative will improve low-income households' welfare relative to present trends.

This RLF program relies on credit scores for loan eligibility, meaning that many households with low credit scores are likely to continue to experience credit rationing (Gillingham & Palmer, 2014; Palmer et al., 2012). That said, the city's risk portfolio standards will increase some lower-income households' access to efficiency loans and allow them to enjoy energy savings. Although participating households will find the no-interest loans affordable, undergoing a credit check and incurring additional debt may affect a household's ability to access credit for other uses (Mundaca & Kloke, 2018).

The RLF program could be used to support energy efficiency upgrades for both homeowners and renters, but it is unlikely that many renters would participate in the program. Since renters do not own the property they live on, they will not receive capital gains from increased property values, and they will be unable to pass the loan onto future renters because it is not attached to their property meter. Thus, renters who are uncertain about their length of stay in their current residence will have little incentive to participate in the program. On balance, the increase in efficiency upgrade accessibility will be smaller for renters than for homeowners, as renters are also more likely to have lower credit scores (Li & Goodman, 2016).

FEASIBILITY

This alternative performs moderately well with regard to the feasibility criterion and receives a rating of medium with a score of 3. The city government is familiar with RLF program management, as direct communications between C3 and city officials revealed that Charlottesville has created an RLF in the past. With this existing expertise, the city could avoid most startup costs and capacity building efforts, making this alternative highly administratively feasible. Specifically, this analysis assumes that the city would only need to hire one additional employee to manage the RLF, set up a loan payment portal through the online system, and market the program to Charlottesville residents. The self-sustaining nature of the proposed RLF would further serve to limit administrative costs associated with extending the length of program operation because administrators would be exempt from periodically reallocating funds to the RLF (Deason et al., 2016; Kats et al., 2011).

Although the $8 million required to establish the RLF may hinder this alternative's political feasibility, especially in light of the COVID-19 pandemic's potential to constrain spending on energy efficiency programs, this alternative aligns with the city's stated objective to create funding programs for "increased residential energy performance," as well as C3's commitment to reducing climate pollution (City of Charlottesville, 2020a & 2020c). This alternative's political feasibility is enhanced by its widespread implementation and success in localities across the United States (ACEEE, 2020).

OUTCOMES

	Benefit-Cost Analysis	Equity	Feasibility
Alternative 3: Revolving Loan Fund	**4** **NPV $7,754,859** from 2020-2045	**3** **Medium** Enhances affordability, but does not reach renters or eliminate credit rationing	**3** **Medium** High administrative feasibility due to city's experience, medium political feasibility

ALTERNATIVE 4: LOAN LOSS RESERVE

With this alternative, C3 would propose that the City of Charlottesville create a Loan Loss Reserve (LLR) to attract private lenders to the energy efficiency market. The LLR would provide public funds to private lenders in the event that a borrower defaults on their loan, thereby reducing the risk private lenders face when offering unsecured loans (DOE, 2019b).

The LLR would be created through the reallocation of $1.6 million of city funds, enough to support a lending portfolio that offers $8,000 loans to 1,000 households over a 10-year time span, thereby creating a reserve of 20 percent of the total lending portfolio. After establishing the LLR, the city government would need to contract with one or more private lenders to initiate the energy efficiency loan program. To start, C3 would propose that the city contract with the University of Virginia Community Credit Union (UVA CCU), the same financial institution the city partnered with to offer the now-suspended Reduced Interest Rate PowerSaver Loan program. Depending on UVA CCU's lending capacity, the amount of funding available, and the initial success of the program, C3 could later propose that the city expand the LLR and partner with additional private lenders.

Precise payouts from the LLR – between 80-100 percent of loan losses – would be made according to the prespecified terms of the loan loss agreement made with UVA CCU, as well as any other financial institutions that partner with the city government in the future. In developing these agreements, the city would further specify risk portfolio parameters to ensure that the privately-offered loans reach the target population of low-income and cost-burdened households without incentivizing private lenders to engage in riskier lending behavior. The private lender(s) would then be able to determine loan eligibility according to customer characteristics, likely using credit scores as the eligibility criterion, and participating households would repay the efficiency loan over time according to their private lender's interest rate.[9] Since the city's LLR would only be used in the event that defaulting customers impose losses on partnering private lenders, the city government could reallocate the reserve funds for other uses if the default rate was lower than expected.

BENEFIT-COST ANALYSIS

This alternative passes the BCA with NPV $6,986,234 and a score of 3. The benefits of the LLR program include energy savings and improved comfort for the

[9] The program-eligible range of household credit scores would be determined in accordance with the risk portfolio parameters specified in the LLR agreement.

1,000 households that install energy efficiency upgrades, as well as healthcare savings for the Charlottesville community as a result of reduced air pollution. To account for the time it would take the city to contract with private lenders, this analysis assumes that the stream of benefits would start in 2023. The total present value of benefits for this LLR program proposal is $16,032,135.

The costs of this alternative include the resource cost of efficiency upgrades, the opportunity cost of government spending, the administrative costs incurred by the city government and the private lender (i.e., program marketing, labor, and office space), and the transaction costs incurred by participating households. The present value of costs for the program is $9,045,901. See Appendix B for more.

EQUITY

This policy alternative performs poorly with regard to the equity criterion and receives a rating of low-medium with a score of 2. Although establishing the LLR would increase the total quantity of privately-offered energy efficiency loans in Charlottesville, this program would not ensure that the partnering financial institution(s) adequately targets low-income households with energy efficiency loans. UVA CCU, or any other private lender, is likely to use credit scores as the participant eligibility criterion, meaning that lower-income households with low credit scores may continue to be credit rationed (Palmer et al., 2012). Households participating in the LLR-backed efficiency financing program will also undergo a credit check and incur additional debt, potentially affecting their ability to access credit for other purposes in the future (Mundaca & Kloke, 2018).

Financing literature indicates that LLRs incentivize private lenders to offer lower-than-market interest rates, often in the 5-10 percent range (Palmer et al., 2012). Even though these interest rates are below market rates, if cost-burdened and low-income households are approved for energy efficiency loans, the interest rates associated with these loans may still reduce their affordability and increase the risk of loan default. Furthermore, this program is not well-suited to reach renters because it ties the loan to the original applicant rather than the property meter; renters may be unlikely to apply for efficiency loans through this program unless they are certain that they will reside in the same property for the entirety of the loan payment period.

While the costs of this alternative are primarily borne by the city government and partnering private lenders, the benefits will be narrowly distributed among Charlottesville residents, leading this policy to receive a low-medium equity rating.

FEASIBILITY

This alternative performs well with regard to the feasibility criterion and receives a rating of medium-high with a score of 4. The city government has experience with public-private partnerships for energy efficiency lending, as it used a similar program design in the past for its Reduced Interest Rate PowerSaver Loan program (City of Charlottesville, 2020a). The city's familiarity with this design and local financial institutions like UVA CCU will limit the transaction costs associated with engaging with private lenders, making this program administratively feasible. By partnering with private lenders who are familiar with efficiency lending, the city can also limit the administrative costs (i.e., program marketing and labor) faced by the private lenders. That said, the scale of efficiency lending offered by this program will be limited by the city government's willingness to bear additional administrative costs. If it is willing to coordinate and contract with multiple private lenders, the city will need to allocate resources to the program's management over and above the additional employee it will need to hire to manage the LLR.

More than 30 states and localities have established LLR-backed energy efficiency financing programs; this policy alternative's political feasibility is enhanced by the success of LLR programs in other localities (DOE, 2019b). Moreover, this program aligns with C3's mission and the city's energy efficiency goals. Specifically, the city aims to address "Financing Options to Enable and Support Private Sector Action" in its forthcoming Climate Action Plan (City of Charlottesville, 2020a). With this goal in place, this analysis finds that allocating $1.6 million to a public-private efficiency lending program in Charlottesville is politically feasible unless the global COVID-19 pandemic constrains spending on energy efficiency initiatives (City of Charlottesville, 2020c).

OUTCOMES

	Benefit-Cost Analysis	Equity	Feasibility
Alternative 4: Loan Loss Reserve	**3** **NPV $6,986,234** from 2020-2045	**2** **Low-Medium** Non-zero interest rates reduce affordability; does not reach renters or eliminate credit rationing	**4** **Medium-High** High administrative feasibility due to city's experience, medium political feasibility, low funding requirements

OUTCOMES MATRIX

	Benefit-Cost Analysis (30%)	Equity (40%)	Feasibility (30%)	Overall Score
Alternative 1: Let Present Trends Continue	**1** **Baseline** from 2020-2045	**1** **Low** Rising electricity prices will reduce welfare of low-income households	**4** **Medium-High** High administrative feasibility, medium political feasibility	**1.9**
Alternative 2: On-Bill Financing	**5** **NPV** **$7,824,304** from 2020-2045	**5** **High** Reduces credit rationing, enhances affordability, and reaches renters	**2** **Low-Medium** Low administrative feasibility, medium political feasibility	**4.1**
Alternative 3: Revolving Loan Fund	**4** **NPV** **$7,754,859** from 2020-2045	**3** **Medium** Enhances affordability, but does not reach renters or eliminate credit rationing	**3** **Medium** High administrative feasibility due to city's experience, medium political feasibility	**3.3**
Alternative 4: Loan Loss Reserve	**3** **NPV** **$6,986,234** from 2020-2045	**2** **Low-Medium** Non-zero interest rates reduce affordability; does not reach renters or eliminate credit rationing	**4** **Medium-High** High administrative feasibility due to city's experience, medium political feasibility, low funding requirements	**2.9**

MATRIX METHODOLOGY

Policy alternatives are scored on a 1-5 scale for each criterion, and criterion scores are weighted such that overall scores are out of 5. The general formula used to calculate the overall score is: (BCA score x 30%) + (Equity score x 40%) + (Feasibility score x 30%). For example, the overall score calculation for Alternative 1: Let Present Trends Continue is (1 x 30%) + (1 x 40%) + (4 x 30%) = 1.9. See Appendix C for more information on scores.

RECOMMENDATION

This analysis recommends that C3 move forward with **Alternative 2: On-Bill Financing.** Each policy alternative structures energy efficiency lending to increase the availability, affordability, and accessibility of energy efficiency upgrades, and all of the alternatives pass the BCA with similar NPVs. After careful consideration of the criteria and the equity of each alternative, the OBF program has the greatest potential to equitably improve Charlottesville's residential energy efficiency, and it most directly addresses the market failures that contribute to the energy efficiency gap. Implementing the OBF program will support the Charlottesville City Council's stated commitment to address equity in its Climate Action Plan and to develop residential energy efficiency programs that are compatible with affordable housing and renter-occupied housing (City of Charlottesville, 2020a).

While this alternative requires trade-offs on administrative feasibility, C3 can support the program and reduce Charlottesville Gas's startup costs by sharing best practices, lessons learned, and resources from the OBF program administrators C3 has interviewed and surveyed. Moreover, building capacity to advance this innovative program design will enhance C3's mission by elevating Charlottesville's climate leadership.

For the OBF program to reach its target population, C3 and Charlottesville Gas must make efforts to educate Charlottesville residents about the availability and affordability of efficiency upgrades through the program. Although the OBF program addresses the high upfront cost of efficiency upgrades, it does not on its own generate demand for energy efficiency upgrades. To generate demand and fill informational gaps, this analysis recommends that C3 and Charlottesville Gas partner to pair the OBF program with an information campaign.

IMPLEMENTATION

To move forward with this recommended policy alternative, C3 must first create a detailed proposal for the OBF program that includes an anticipated implementation timeline and program design recommendations. After developing the OBF proposal, C3 should meet with a number of key stakeholders in the city government, starting with its contacts in the Environmental Sustainability Division who initially requested that C3 investigate options for a residential energy efficiency financing program.

Through discussions with officials from the Environmental Sustainability Division, C3 can gain a better understanding of the program's feasibility and the city government's internal decision-making processes. With this information, C3 can determine areas for improvement and make necessary revisions to its proposal. Moving forward, C3 should arrange a meeting with its allies from the Environmental Sustainability Division and officials from Charlottesville Gas to pitch the OBF proposal. Assuming Charlottesville Gas officials express interest in the proposal, further discussions should involve the City of Charlottesville Office of Budget and Performance Management, the Department of Finance, and the Utility Billing Office, as these offices and departments have control over program funding and the tariffed on-bill payment process.

C3 could alternatively propose the program to the Charlottesville City Council and advocate for it to adopt an ordinance or resolution that requires Charlottesville Gas to implement an OBF program. However, the OBF program is more likely to be successful if Charlottesville Gas agrees to operate the program through internal processes and negotiations, as the degree of a utility's commitment to OBF is a key determinant of its success (Mundaca & Kloke, 2018; Durkay, 2016).

If Charlottesville Gas agrees to initiate and operate the OBF program, it will need to work with C3 and the aforementioned stakeholders to include a provision for OBF program funding in Charlottesville's FY 2022 budget. Budget planning for FY 2022 will begin in September 2020, and the proposed budget will be submitted by the City Manager to City Council by March 15, 2021 (City of Charlottesville, 2020e). It is important that C3 considers the budgetary timeline. If C3 does not work quickly to arrange meetings and coordinate an agreed-upon program plan with Charlottesville Gas in the next six months, this program is unlikely to be included in the FY 2022 budget and will remain unviable until at least FY 2023.

In the wake of the global COVID-19 pandemic, the City Manager and City Council may not agree to allocate funding to the OBF program. Although City Council's Strategic Plan includes "A Beautiful and Sustainable Natural and Built Environment" as one of its main goals, environmental sustainability is likely to be deemphasized in favor of public health initiatives in the next few years (City of Charlottesville, 2020c & 2020e). C3 should consider other options in the event that the program is denied funding; one option is for C3 and Charlottesville Gas to acquire third party funding from financial institutions like UVA CCU and establish an On-Bill Repayment program (Durkay, 2016).

If Charlottesville Gas rejects C3's proposal, C3 should be prepared to pivot and instead propose that Charlottesville's water utility operate the OBF program. Though unintuitive, the water utility could operate the program in the same way as Charlottesville Gas and charge customers through their water bills based on the expected energy savings.[10] Alternatively, C3 could propose the RLF program if none of Charlottesville's municipal utilities are willing to provide this energy efficiency service.

Once the OBF program is initiated, C3's role should involve program marketing and assessment. Energy efficiency financing programs often struggle to generate demand, meaning that market penetration tends to be lower than expected (Palmer et al., 2012). C3 should work with Charlottesville Gas to establish an information campaign on energy efficiency to reach the target population of low-income and cost-burdened households and achieve the desired market penetration rate.

To target this population, C3 should reach out to Charlottesville Gas customers that have submitted complaints about their utility bills, network with its community partners to share information about the program, and use social media to raise public awareness of the program. Any marketing materials should leverage lessons from the psychological literature on influence and nudges (Sunstein & Thaler, 2008; Cialdini, 1984). For example, advertisements that use negative framing (i.e., stop wasting energy and money) may be more likely to encourage program participation than positively framed ads (i.e., save energy and money) (Chou & Murnighan, 2013). As C3 leads this information campaign, it should also collect data on the OBF program in order to assess its progress over time and allow for future program evaluation.

[10] Savings would appear on a household's electric and gas bill, and households would pay through their water bill.

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APPENDIX A: ON-BILL FINANCING CASE STUDY

How$mart® is a tariffed OBF program that has been operating in Kansas since 2007. Midwest Energy, a local energy cooperative in western Kansas, designed the program using the Pay As You Save® (PAYS®) model developed by The Energy Efficiency Institute, Inc. (Mundaca & Kloke, 2018; SEE Action, 2014; Johnson et al., 2011). As of 2017, How$mart® was one of 17 programs offering PAYS®-based residential energy efficiency programs across the United States (SEE Action, 2017).

Consistent with the PAYS® model, Midwest Energy invests in energy efficiency upgrades, attaching the investment to the property meter, and allows program participants to repay the investment through a charge on their utility bill. Thus, the participants do not consider the investment as debt, and the investment can be transferred between occupants because it is attached to the property meter (SEE Action, 2017).

From 2007 to 2014, How$mart® reached 1,184 households with an average investment of $6,000 (Mundaca & Kloke, 2018; SEE Action, 2014). Midwest Energy actively reached out to customers with "above-average energy use," and 55% of these customers agreed to participate in the program and install upgrades (Mundaca & Kloke, 2018). The program has also been successful in addressing the split incentive between renters and landlords; 14% of upgrades involve renters, consistent with the 14.6% of households in the service area that occupy rental properties (Mundaca & Kloke, 2018; Johnson et al., 2011).

> ***"The PAYS system directly addresses most of the major barriers to implementation: it provides inclusive access to financing, local contractors, and technical expertise; creates immediate cash flows; delivers quality control and consumer protections; and mitigates the uncertainty that comes with recouping the investment if the participant needs to move or rent the home."***
>
> ***– Chris Woolery, MACED Residential Energy Coordinator***

The How$mart® program is still in operation today, and it inspired the establishment of How$martKY™ in 2010. Operated by the Mountain Association for Community Economic Development (MACED), which coordinates with four electric cooperatives across Kentucky, the How$martKY™ program reaches up to 50 households each year; in 2012, more than 80 households were reached with an average investment of $5,767 (Woolery, personal communication, 2020; SEE Action, 2014). The program's real customer default rate is 0.4%, consistent with the literature that suggests that OBF programs have default rates lower than 2% on average (Durkay, 2016; Johnson et al., 2016; Palmer et al., 2012; Bell et al., 2011).

How$martKY™ was initiated with the objective of expanding inclusive PAYS financing to help low-income populations facing high energy bills. The program is supported by residents in the targeted communities, and financial analyses have revealed that both participating utilities and households have received "strong financial returns" (Woolery, personal communication, 2020).

Recently, the program has faced challenges with stakeholder engagement, and targeted program promotions, though successful in the past, have been limited. Through direct communications, Woolery indicated that the fall in stakeholder engagement and program demand may be attributable to the fact that the Federal Clean Power Plan, which would have disproportionately raised energy burdens faced by low-income, coal-dependent communities, did not go into effect (Woolery, personal communication, 2020; Van Velzer, 2018).

APPENDIX B: BENEFIT-COST ANALYSIS

The BCA evaluates the benefits and costs of each alternative using a 3.5 percent discount rate and a 25-year time horizon from 2020 to 2045. The tables below present the analysis assumptions used for the NPV calculations and the breakdown of benefits and costs for each alternative along with a brief description of the methodology.

Disclaimer: This BCA includes many assumptions, most of which are derived from relevant research and are cited accordingly. Other assumptions are generated by the author of this report. The sensitivity analysis accounts for some of the uncertainties and limitations of the analysis, but this BCA is best used as a tool for comparison between the alternatives.

Table 1. All BCA Assumptions

General Assumptions		
All costs occur at year end	year end	Standard practice
All $ are in 2019$	2019$	Author decision
Discount rate	3.5%	Author decision
Number of new households participating each year	100	The Energy Efficiency Institute, Inc., 2016
Program lifetime (of upgrade offerings) in years	10	Author assumption
Avg cost of efficiency upgrade per household	$8,000	NREL, 2017
Avg annual energy savings in kWh per household	4800	Wilson et al., 2017
Avg rebound effect per household	20%	Gillingham et al., 2014
Maximum loan term in years	15	Author assumption
Avg monthly electricity use in kWh per VA household	1165	EIA, 2018
Avg yearly electricity bill per VA household	$1,639	EIA, 2018
$/kWh price of electricity in 2019	0.1173	EIA, 2019
Avg annual energy savings as % of total energy use	34%	Author calculation
Avg rent per square ft of office space per year	$18	HR&A Advisors, Inc., 2018
Standard cubicle size in square feet	64	Voss, n.d.
Deadweight loss scalar for government spending	1.25	Campbell & Brown, n.d.
Avg value of comfort as % of utility bill savings	13.5%	Russell et al., 2015
Median residential property value in Charlottesville	$289,678	ACS, 2017
Avg % increase in property value for efficient homes	2%	Chegut et al., 2016
Number of households in Charlottesville	18,613	U.S. Census Bureau, 2019
Annual health-related savings per household	$796.66	Tonn et al., 2014
Charlottesville bond interest rate	2.36%	Department of Finance, 2019
Cost of program marketing per participant	$241	Mundaca & Kloke, 2018
Minimum wage in Virginia	$7.25	Glasmeier, 2020

Present Trends		
Annual increase in $/kWh (electricity price)	3.20%	Miller, 2017
Price elasticity of electricity demand	-0.4	Deryugina et al., 2017
On-Bill Financing		
Estimated salary for Charlottesville Gas employee	$80,000	Stout, 2019
Number of new employees for program operation	1.00	The Energy Efficiency Institute, Inc., 2016
Additional hours spent on repayment each year	0.00	Author assumption
Revolving Loan Fund		
Estimated salary for Charlottesville government employee	$80,000	Stout, 2019
Number of additional employees for program operation	1.00	The Energy Efficiency Institute, Inc.
Number of additional hours per year spent on repayment	1.00	Author assumption
Loan Loss Reserve		
Estimated salary for Charlottesville government employee	$80,000	Stout, 2019
Number of additional gov't employees for program	1.00	The Energy Efficiency Institute, Inc., 2016
Number of additional hours per year spent on repayment	1.00	Author assumption
Estimated salary for financial institution employee	$80,000	Glasmeier, 2020
Loan loss compensation rate	90%	Author assumption
Estimated default rate	4.5%	Palmer et al., 2012; Farrell, 2016

Additional Information on Valuation Techniques: The assumptions underlying the valuations of improved comfort and healthcare savings are drawn from existing literature. Energy efficiency upgrades that produce energy savings can also improve a households' level of comfort and health. Including co-benefits in the BCA is important as they often motivate households to invest in energy efficiency upgrades and they substantially increase the present value of benefits (Russell et al., 2015).

Literature indicates that the value range of **improved comfort** is between 2-25 percent of energy savings; this data is derived from a number of studies that survey participants in residential energy efficiency programs (Russell et al., 2015). This BCA uses the average of this value range – 13.5 percent – to represent the value of improved comfort as a percent of energy savings.

The estimate of **healthcare savings** per household is drawn from a study of the DOE's Weatherization Assistance Program (WAP), which funds efficiency upgrades for low-income households. The study conducted by researchers at Oak Ridge National Laboratory estimates that the present value of health-related benefits per weatherized household is $16,884 in real 2019$ (Tonn et al., 2014). However, this analysis finds the present value of those health-related benefits estimated with the greatest certainty from "observable monetized outcomes," which includes benefits related to asthma, thermal stress, and fewer days of missed work (Tonn et al., 2014). By reverse engineering this present value estimate of $7,923, this analysis calculated an annual healthcare savings benefit of $796.66 per household, which includes benefits to society.

The **transaction costs incurred by participating households** for the RLF and LLR policy alternatives are estimated using the minimum wage as the opportunity cost of program participants' time. This cost estimation relies on a strong assumption that the average wage of Charlottesville's low-income households is the minimum wage. In fact, this may underestimate the value of transaction costs, as the mean wage of renters in Virginia is $18.27 (National Low Income Housing Coalition, 2019).

For additional information, please view the spreadsheet that includes calculations:

https://www.dropbox.com/s/u443klpzq1ae0f5/Checknoff_Ruth_APP_BCA.xlsx?dl=0

ALTERNATIVE 1: LET PRESENT TRENDS CONTINUE

The following table illustrates present trends for selected years in the 25-year time horizon from 2020-2045. This status quo alternative serves as the baseline for the BCA, meaning that all benefits and costs calculated for the other three policy alternatives are considered relative to present trends. Thus, there are no costs or benefits projected under present trends, and it is not possible to assign a net present value to the baseline.

Table 2. Present Trends Summary of Benefits and Costs

		Year	
Trend	2020	2030	2045
$/kWh price of electricity in VA	0.1173	0.1607	0.2578
Per household spending on electricity (if zero price elasticity of demand)	$1,639.85	$2,246.99	$3,604.11
Per household kWh consumption (if -0.4 price elasticity of demand)	13,980	12,290.19	10,130.62
Per household spending on electricity (if -0.4 price elasticity of demand)	$1,639.85	$1,975.39	$2,611.72

ALTERNATIVE 2: ON-BILL FINANCING

The following table presents the present value of categories of costs and benefits for the OBF program. All items in the Method of Calculation section refer to assumptions listed in Table 1. All benefits and costs start in 2022 (year 2), with the exception of employee salary and office space costs, which start in 2021 (year 1); this analysis assumes that funding for efficiency upgrades would not become available until FY 2022, but program set-up would begin as soon as the program receives funding approval in FY 2021. Note that value transfers within the scope of this analysis are not considered real benefits or costs, and are not included in the NPV of each alternative. The equity criterion used earlier in this analysis considers transfers and the distribution of benefits and costs.

Table 3. On-Bill Financing Summary of Benefits and Costs

	Present Value	**Method of Calculation**
Benefits		
Energy savings	$6,903,676.21	kWh savings w/ rebound effect * $/kWh * # of households
Improved comfort	$931,996.29	Comfort as % of energy savings * energy savings $ amount
Healthcare savings	$9,298,468.55	Healthcare savings per household * # of households
Total benefits	*$17,134,141.04*	
Costs		
Efficiency upgrade resource cost	$6,428,293.97	Avg resource cost * # of participating households
Opp. cost of gov't spending on upgrades	$1,301,970.15	Total $ outstanding * bond interest rate * DWL scalar
Employee salary cost	$1,318,521.17	Estimated salary (constant over time horizon)
Office space cost	$18,986.70	$/square foot of office space * cubicle size
Marketing cost	$193,652.36	Marketing cost/participant * # of participating households
Opp. cost of gov't spending on marketing	$48,413.09	Total marketing cost * DWL scalar
Total costs	*$9,309,837.44*	
Net Present Value	**$7,824,303.61**	

ALTERNATIVE 3: REVOLVING LOAN FUND

Table 4 presents the present value of benefits and costs for the RLF program. All benefits and costs are valued in the same manner as Alternative 2: On-Bill Financing, with the exception of transaction costs for program participants. This analysis assumes that making an additional loan payment 12 months of the year requires one hour of time per household, and the minimum wage is used to value time given the characteristics of the program's target population of low-income households.

Table 4. Revolving Loan Fund Summary of Benefits and Costs

	Present Value	**Method of Calculation**
Benefits		
Energy savings	$6,903,676.21	kWh savings w/ rebound effect * $/kWh * # of households
Improved comfort	$931,996.29	Comfort as % of energy savings * energy savings $ amount
Healthcare savings	$9,298,468.55	Healthcare savings per household * # of households
Total benefits	*$17,134,141.04*	
Costs		
Efficiency upgrade resource cost	$6,428,293.97	Avg resource cost * # of households
Opp. cost of gov't spending on upgrades	$1,301,970.15	Total $ outstanding * bond interest rate * DWL scalar
Employee salary cost	$1,318,521.17	Estimated salary (constant over time horizon)
Office space cost	$18,986.70	$/square foot of office space * cubicle size
Marketing cost	$193,652.36	Marketing cost/participant * # of households
Opp. cost of gov't spending on marketing	$48,413.09	Total marketing cost * DWL scalar
Participant transaction costs	$69,444.68	Time for payment * min. wage * # of households
Total costs	*$9,379,282.12*	
Net Present Value	**$7,754,858.93**	

ALTERNATIVE 4: LOAN LOSS RESERVE

Table 5 summarizes the present value of benefits and costs for the LLR program. All benefits and costs start in 2023 (year 3), with the exception of employee salary and office space costs, which start in 2022 (year 2). This analysis assumes that the LLR program would require an additional year to begin operations because the city government would need to contract and negotiate with one or more private lenders.

Table 5. Loan Loss Reserve Summary of Benefits and Costs

	Present Value	Method of Calculation
Benefits		
Energy savings	$6,496,750.86	kWh savings w/ rebound effect * $/kWh * # of households
Improved comfort	$877,061.37	Comfort as % of energy savings * energy savings $ amount
Healthcare savings	$8,658,322.96	Healthcare savings per household * # of households
Total benefits	*$16,032,135.18*	
Costs		
Efficiency upgrade resource cost	$6,210,912.05	Avg resource cost * # of participating households
Opp. cost of gov't LLR payouts	$62,885.48	LLR payouts * DWL scalar
Employee salary cost for gov't	$1,241,226.48	Estimated salary (constant over time horizon)
Office space cost for gov't	$17,873.66	$/square foot of office space * cubicle size
Employee salary cost for private lender	$1,241,226.48	Estimated salary (constant over time horizon)
Office space for private lender	$17,873.66	$/square foot of office space * cubicle size
Marketing cost for private lender	$187,103.73	Marketing cost/participant * # of participating households
Participant transaction costs	$66,799.90	Time for payment * min. wage * # of households
Total costs	*$9,045,901.44*	
Net Present Value	**$6,986,233.74**	

SENSITIVITY ANALYSIS

This sensitivity analysis includes an elasticity analysis, a breakeven analysis, and a crossover analysis to evaluate the sensitivities and limitations associated with the BCA.

The elasticity analysis reveals that for the three non-baseline alternatives, the NPV is inelastic with respect to most variables, meaning that for a 1% change in the variable, the NPV changes by less than 1%. For example, the NPV is inelastic with respect to the discount rate and the value of comfort that a household enjoys after installing energy efficiency upgrades. Additionally, the NPV of each alternative is inelastic with respect to the annual percent increase in electricity rates; this finding is particularly important because no models have yet been able to predict electricity rates in a manner that comprehensively accounts for Virginia's recent environmental policies. On the other hand, the elasticity analysis finds that the NPV of each policy alternative is sensitive to the number of new households participating in the program each year, the value of healthcare savings, and the amount of kWh energy savings for participating households.

The breakeven analysis considers what would drive the NPV of each alternative to $0. All else equal, the per household healthcare savings and kWh savings would have to drop below $154 and 253 kWh, respectively, to drive the NPV of LLR to $0, but these values fall outside of the likely range of estimates. Considering the number of new households participating in the program each year as a critical variable, this analysis finds that OBF and RLF would have negative NPVs if the number of new households participating in the program fell below 15 each year. For LLR, program reaches of less than 27 households each year would result in a negative NPV. Although it is possible for an energy efficiency financing program to have program reach on the order of 10-50 households per year, research indicates there is a low probability that a residential efficiency financing program will reach fewer than 15 households per year (SEE Action, 2014). This finding supports the recommendation that C3 conduct an information campaign to generate demand for the OBF program and ensure sufficient program reach.

The crossover analysis finds that OBF and RLF would have the same NPV if households participating in the RLF program required no additional time to make the loan payment. Further, the LLR would be preferred to both OBF and RLF if Charlottesville's bond interest rate, which is used to value the opportunity cost of government spending, is greater than 3.75%. However, Charlottesville's current bond interest rate is 2.36%, so this crossover is very unlikely to occur in practice (Department of Finance, 2019).

After accounting for limitations and the uncertainty of estimates, the sensitivity analysis supports the recommendation of Alternative 2: On-Bill Financing, as it has the highest NPV under all likely scenarios, and program reach would have to be less than 15 households per year for the program's NPV to become negative, all else equal.

APPENDIX C: SCORING SYSTEM INFORMATION

Criterion scores are assigned to the policy alternatives for the purpose of comparison and evaluation of trade-offs between the alternatives. All scores are integers.

For the equity and feasibility criteria, the scores correspond to ratings of low (1), medium (3), and high (5). Any alternatives with low-medium or medium-high qualitative ratings receive a score of 2 or 4, respectively. Scores and qualitative ratings are assigned based on the likely outcome of each policy alternative.

For the benefit-cost analysis criterion, scores are assigned solely for the purpose of comparison and criteria weighting. The scores are relative – the alternative with the highest NPV receives a score of 5, and the alternative with the lowest NPV receives a score of 3. This scoring system is used because of the relative proximity of the policy alternatives' NPVs.

Once scored, each alternative's overall score was determined by applying the criteria weights, as explained in the Matrix Methodology section of this report.