EQUITABLY FINANCING BUILDING DECARBONIZATION MEASURES

Actionable Strategies for Utilities

December 2022

Executive Summary

Events over this past year have brought to the fore the importance of accelerating efforts to remove reliance on fossil fuels to mitigate the worst impacts of climate change and ensure reliable and secure energy supply, while also improving energy affordability. Decarbonizing buildings will be a critical part of achieving carbon reduction goals and improving living standards for marginalized customers and communities. This paper provides recommendations of actionable strategies for utilities to equitably finance building decarbonization by examining the following questions:

- What is the case for decarbonizing buildings from an end-user, utility, and societal perspective?
- What are the emerging financing mechanisms, business models, and engagement approaches to advance equitable decarbonization? And what are their respective benefits and challenges?
- What metrics can improve assessments of programs and policies?

Key challenges include engaging customers, financing upfront costs, and addressing the split-incentives between tenants and landlords that exist in renter-occupied buildings. Emerging on-bill repayment (OBR) financing models that leverage a tariff-on-bill (TOB) repayment mechanism show promise as they eliminate the upfront cost, do not attach debt to the individual, reduce the rate of payment default, offer bill-neutrality, and alleviate split incentive challenges by allowing for payer transferability. One-stop-shop (OSS) services that combine digital tools and effective program coordination among dedicated retrofit teams and partners could help to engage and support more customers, making it as easy as possible for customers to access the benefits of building decarbonization. OSS services also offer opportunities for utilities to improve trust and satisfaction amongst existing customers and to attract new customers in competitive supplier markets like Europe.

In each case, collaboration and development of appropriate performance metrics will be key to any effective strategy for decarbonizing buildings in an equitable fashion. This will involve utilities working closely with financial institutions, contractors, installers, equipment manufacturers, and local non-profit community organizations that are already heavily involved with marginalized customers and communities.

Introduction

In the wake of COP26 and increasingly volatile fossil fuel markets, energy prices, and extreme climate events, nations are setting more ambitious decarbonization goals. Over 2,000 jurisdictions covering over 1 billion global citizens have declared climate emergencies [1] and many more have set targets to achieve net zero carbon emissions in a bid to limit the worst impacts of climate change. Constructing and operating buildings is associated with 38% of global carbon emissions, with 28% of emissions associated with energy consumed during the operational life of a building. The electric power industry can play a pivotal role in decarbonizing buildings and transportation through widespread electrification.

The increasing reliance on power grids means that electric utilities must set in motion comprehensive plans to upgrade the infrastructure needed to generate, transmit, and supply electricity to reliably meet

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the increasing demand of future energy systems. Meanwhile, the role of customers and buildings is changing from consumers to suppliers of electricity, energy storage, and flexibility services furthering the complexity of energy systems. Incorporating comprehensive strategies to decarbonize and to improve the efficiency and grid value of buildings could have significant value for society and utilities.

As decarbonization progresses and energy systems transition, equity and energy affordability are becoming increasingly important topics to address. Approximately 13% of the world's population still lacks access to electricity. In the US, 25% of households are experiencing a high energy burden, while some 50 million Europeans live in energy poverty with this expected to increase drastically as supply insecurities influence increasing energy prices [2]. These circumstances highlight the need for a more democratic energy system with equitable access to clean energy technologies that decarbonize energy use, reduce energy costs, engage community members in their energy system, and improve quality of life.

A recent EPRI white paper [3] outlined high-level strategies and actions available to utilities when developing roadmaps for building decarbonization in response to policy, market, and technology drivers (Figure 1). Key challenges with implementing building decarbonization action plans include engaging customers to act and addressing upfront costs, while tackling the challenge of split-incentives remains an additional consideration in rental properties, which made up 36% of households in the US in 2019 [4]. In existing buildings, there are other challenges which add to the cost, complexity, and time to decarbonize, including the need to upgrade the electrical capacity in previously dual fuel environments and the need to abate for asbestos and lead in older buildings. These challenges make it disproportionally difficult for energy poor households to access the benefits of building decarbonization. It also means that regional strategies for financing building decarbonization may differ depending on the specific technical, social, and regulatory landscape.

Communities and customers may be able to access incentives, rebates, and financing mechanisms to offset all or part of the up-front cost of building decarbonization measures through existing utility or government programs. This report aims to offer utilities insights into existing and emerging models for engaging customers to overcome the known barriers to financing the decarbonization of existing buildings. To achieve this the following questions are investigated:

- What is the case for decarbonizing buildings from an end-user, utility, and societal perspective?
- What are the current and emerging financing mechanisms, business models, and engagement approaches? And what are their respective benefits and challenges?
- What metrics can improve assessments of the impact and effectiveness of equitable decarbonization programs and policies?

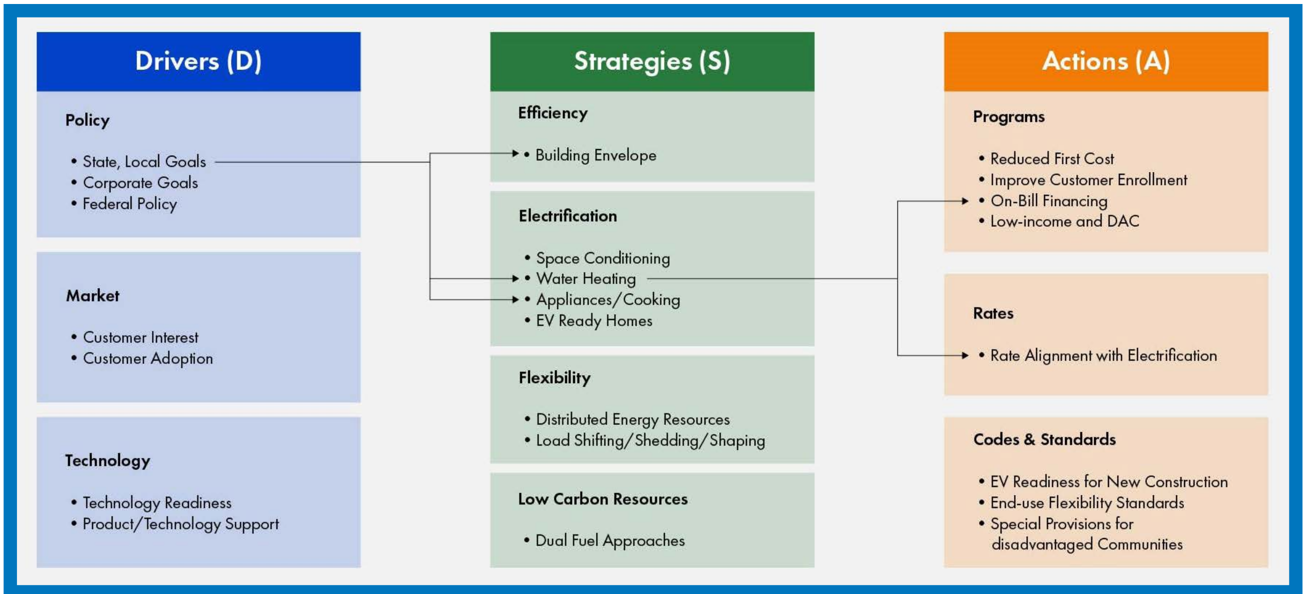

Figure 1. Building decarbonization strategies are developed by utilities using Actions pertaining to a Strategy in response to a Driver [3]

Defining the Customers and Challenges with Equity and Engagement

Marginalized communities encompass people from a variety of backgrounds that may have endured systemic injustice historically and in the present day within our energy, economic, political, and social systems [5]. While this commonly includes low-income (LI) communities, tenants, and black, indigenous, and people of color (BIPOC) communities, energy system disparities can reflect injustice based on other factors such as gender [6], medical status [7], geography [8], and age [9]. If paired with a deliberate effort to remediate social and economic inequities, building decarbonization could bring significant benefits to these communities, who have been denied the financial means or rights necessary to fully participate and benefit from the energy transition.

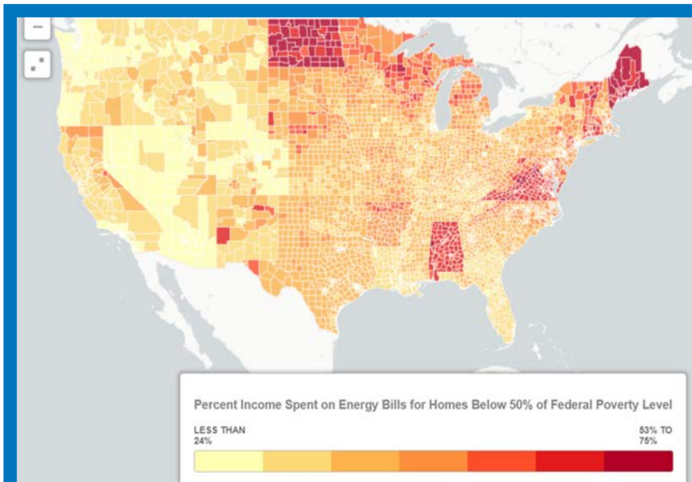

Figure 2. Share of income spent on energy bills by region in the US. [108]

Energy affordability is a commonly used term in the energy industry to identify marginalized households who may require energy assistance. It refers to a household's ability to pay its energy bills (i.e., energy burden) – often based on the proportion of income that goes towards energy costs. According to many standards, energy affordability becomes an issue when energy costs exceed 6% of household income, and energy poverty occurs at 10% of household income [10]. Figure 2 depicts the percent of income spent on energy bills for US households living 50% below the federal poverty line in 2020, showing alarming levels of energy poverty in swathes of the Midwest, South, and East regions of the country.

Energy affordability issues can be further exacerbated by extreme weather events, poor housing stock, and supply chain disruptions, that have become increasingly common due to the climate crisis, the COVID pandemic, and current geopolitical tensions. These groups are also more vulnerable to public health risks associated with high heating and cooling costs in extreme climates, mold, asbestos, indoor combustion, and power outages. While utilities and governments have traditionally offered affordable rates and weatherization programs to income-eligible customers, disparities remain severe, and many assistance programs have been cited as insufficient.

In addition to the limited purchasing power or property rights of marginalized groups, there are other equity considerations that have historically challenged the effectiveness of building decarbonization programs and financing initiatives. In rural areas, the US household energy burden is 42% greater than the median metropolitan household energy burden. The fuel mix and regulatory structure can also be distinct. The low density and limited workforce make programmatic implementation costs high. On the other hand, urban areas bring their own unique challenges to programs and financing with a disproportionately high number of multifamily buildings and renters, for whom there are limited property rights and access to housing improvements and a split incentives between renter and landlord. The split incentive condition is often present for renter households, the landlord or owner may not be inclined to make necessary upgrades to building services when the benefits associated with the resulting energy savings accrue to the tenant, the energy bill holder, and tenants have little incentive to make investments in a property that they do not own [5].

To maximize adoption among these groups, programs should offer achievable pathways to decarbonization benefits by helping to address systemic inequities within our energy system. This includes social, economic, and environmental facets of the energy system. This paper will highlight several actionable strategies with potential to advance equitable building decarbonization.

The Case for Building Decarbonization

The decarbonization of buildings at scale and the equitable distribution of its benefits makes business sense for society, end-users, and utilities. According to the World Meteorological Organization, the number of weather-related disasters has increased globally over the past 50 years [12]. Building decarbonization directly confronts the climate crisis by reducing or eliminating greenhouse gas (GHG) emissions that contribute to an increase in climate- and weather-related disasters globally.

In the US, the National Oceanic and Atmosphere Administration has reported a steady rise in weather and climate disasters with damages exceeding one billion dollars over the last 40 years, as depicted in Figure 3. Each of the 50 US states has now had at least one billion-dollar disaster. In 2020, the US had a record 22 climate- and weather-related events exceeding $1 billion in costs and damages [13]. While the trends over this period are less clear in Europe, between 1980-2020 total economic losses due to climate- and weather-related events amounted to EUR 450-520 billion, with heatwaves responsible for the most fatalities (over 85%) [14].

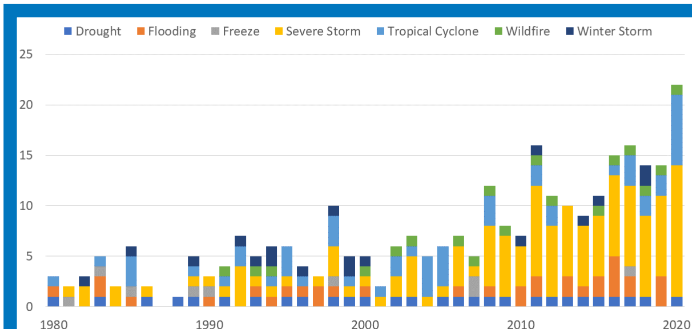

Figure 3. Number of Billion-Dollar Weather and Climate Disasters in the US [13]

Building decarbonization can also positively impact public health. A recent study estimates that removing energy related emissions from the electric power, transportation, building, and industrial sectors in the contiguous US could prevent more than 50,000 premature deaths every year, while providing more than $600 billion in benefits from avoided death and illness due to improved air quality, with 69% of the health benefits from emission removal felt in the emitting region [15].

From the customer or end-user perspective, building decarbonization and energy efficiency can lower energy costs and enhance comfort, leading to healthier indoor environments. In Europe, for example, building decarbonization and energy efficiency is coming to the fore via the European Commission's Renovation Wave strategy which aims to double annual energy renovation rates by 2030 to decarbonize heating and cooling and tackle energy poverty, while creating new jobs and improving social infrastructure [16]. If successful, the Renovation Wave is expected to reduce household energy bills by 25%, improve living standards for around 80 million people, and lower gas consumption in homes by up to 43 TWh annually [2].

In the U.S. the recent Inflation Reduction Act (IRA) will inject $369 billion over the next ten years towards clean energy and building electrification and energy efficiency, mostly in the form of tax credits and incentives. Expected impacts include system-wide CO_2 reductions of 31-33% below 2005 by 2030, lower consumer energy costs, the creation of 1.3 million jobs, cleaner air which to reduce related illnesses and deaths, and an increase in GDP of between 0.6 to 0.8%. While this is a monumental injection of capital into the U.S. market towards equitable decarbonization, the ability to achieve the 2030 climate target of 50% economy wide GHG reduc[1]tions will depend on the stacking effect of programs, policy, financing, and efforts at the local, regional, state, and national level [17].

From the utility standpoint, clean energy, electrification, and energy efficiency technologies, which enable building decarbonization, can contribute to increased grid reliability, flexibility, and resilience by reducing demand during peak times and increasing the capacity of energy storage and flexible loads behind-the-meter. In the US, the value of building level efficiency and flexibility is estimated to be worth roughly $31 billion, while reducing annual electricity use by 742 TWh in 2030 [18].

From an energy security standpoint, building decarbonization technologies can reduce the need to invest in centralized utility scale generation, and increase customer resilience while reducing reliance on fossil fuels, which can be both volatile in terms of supply and cost. The IEA have recognized that the nations that have put an emphasis on energy efficiency in the last few decades now see lower consumer energy costs, lower fuel imports, and lower emissions [19].

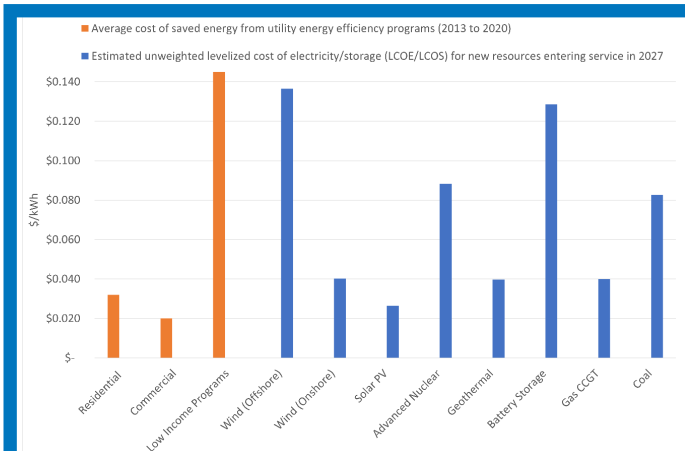

Figure 4. Comparison of the cost of saved energy from EE programs and the estimated cost of new generation and storage deployed in the US in 2027 [20] [21].

Part of the investment in grid infrastructure needed for the decarbonization and electrification of buildings and transport can be counter-balanced with strategic utility demand side management (DSM) programming, which reduces energy consumption and peak energy demand and enables demand flexibility in buildings to aid the integration of variable renewable power. Historically, the estimated annual life cycle cost of residential energy efficiency (EE) programs in the US is about 3 cents per kilowatt hour saved [20], which is cost competitive with the projected cost of building new sources of energy generation and storage (see Figure 4 [21]). However, traditional programs targeting low income (LI) customers have not offered the same rate of cost-effectiveness, with costs from 0.10 to 0.145 $/kWh saved [22], offering an opportunity for further innovation.

Enabling Equitable Financing of Building Decarbonization

Customers interested in reducing energy costs, decarbonizing energy use, or improving the quality and comfort of their home could traditionally access funding via an array of sources and services to help cover the upfront capital cost of building decarbonization and efficiency measures or renewable energy technologies.

Government Initiatives

Governments play a key role in enabling equitable building decarbonization by making funding available via grants or subsidies and by implementing tax breaks for relevant technologies. In the U.S. $500 billion in federal support for clean energy technologies over the next decade has been announced through the Inflation Reduction Act (IRA), the CHIPS and Science Act, and the Bipartisan Infrastructure Law (BIL). Within the BIL federal funds for home improvements via the Weatherization Assistance Program (WAP) are to increase ten-fold to $3.1 billion in 2022 [23]. Notably, the IRA programs targeting the residential and commercial segments are designed to accelerate electrification and energy efficiency. The Home Energy Efficiency Rebate Program includes $9 billion for rebates for home retrofits (up to $14,000 per income qualified household) and for grants for contractor education. Still, there are known barriers that may persist despite this injection of capital that utility programs can help to overcome, including split incentive issues for renters with limited property rights and lack of up-front capital to invest in upgrades.

Funding offered by financial institutions via standard loans or mortgages can help customers to make investments in decarbonization and efficiency technologies. However private loans require customers to be highly proactive in seeking out quality technologies and installers, and they do not traditionally consider the potential monetary savings achieved from reduced energy costs or increased energy production. Unfortunately, it can be difficult for marginalized groups or LI customers to access this type of finance without extensive credit and background checks. While financial institutions have been increasingly offering green loans with more competitive interest rates, they are only applicable to homeowners or individuals with a qualifying credit score. As a result, customers with compromised credit may have difficulty accessing this type of finance.

Considering these limitations, it is important to underscore the existence of many policy and regulatory actions that can serve to leverage funds for investment in building decarbonization. Some of the major avenues proposed for funding climate change mitigation include public borrowing [24] [25] [26], taxation based on wealth and emissions [27], and fiscal policy [28]. Scholars note that climate and energy policies which include social policies designed to uplift vulnerable and frontline communities (i.e., those disproportionately harmed by reliance on fossil fuels [5]) can help to increase the social and political support necessary for accelerating funding for decarbonization [27].

Public borrowing, specifically through green banking, is increasingly viewed as an asset for driving investment in new energy infrastructure [29]. Green banks, often originating under the auspices of state or local government or run by way of a non-profit, can offer private or public entities the ability to access funds when other avenues of public funding are unavailable [30]. While commercial banks have a fiduciary responsibility towards stockholders, public banks are typically oriented towards the interests of the population they serve. As such, they can facilitate investment in public services and projects such as affordable housing or new infrastructure [31] and encourage economic growth while potentially lowering the costs of public interest projects [32].

Green banks can encourage more equitable forms of decarbonization by prioritizing investment in specific regions and sectors [29], particularly rural and environmental justice communities [33]. They may also serve as a pathway for alternative financing mechanisms that reduce the cost of capital required for projects. For example, they can act as the third-party lender in an on-bill repayment scheme [34]. Other benefits include improving financial standards [29], resolving inefficiencies of scale, offering co-investment opportunities, and providing technical assistance and information to borrowers [34].

Further, green banks can fill in gaps in supply and demand [29], utilize financing structures to de-risk investments, and enable more favourable repayment terms on loans [34]. Examples of such financing structures include loan loss reserves funds, which are funds set aside, often by governments, to minimize the impact of borrower default on the lender. Loan guarantees can act as a form of energy savings insurance for capital-intensive energy efficiency investment in marginalized groups by paying out the projected value of energy savings if the energy savings are not achieved. For example, We2Sure offers insurance-based guarantees on clean energy and decarbonization projects [35]. Interest rate buydowns can occur when a third party (governments, philanthropy, or other) essentially subsidizes part of a loan to enable lower interest rates and make a loan more affordable.

Connecticut, New York, and Washington D.C. offer examples of green banks [36], and California's State Treasurer's Office "partially performs as a Green Bank by investing a portion of funds from the Pooled Money Investment Account (PMIA) in bonds that finance green projects throughout the world" [37]. This strategy has recently drawn attention at the federal level. The IRA includes a $27 billion investment in a green bank which will become a clean energy accelerator, with $15 billion of this money to be directed towards disadvantaged communities [38].

Traditional Market-Based Financing and Engagement Models

Electric utilities typically leverage funds gathered via rates on customer energy bills to invest in customer program offerings. Traditionally, utilities have depended on customer programs to engage customers and address issues such as energy affordability. These programs often include direct bill assistance, DSM programs that offer customers financial incentives for managing energy use to reduce peak demand or improve energy efficiency, or direct install services or rebates on certain technology measures. Direct install programs usually address small measures such as lighting, and rebates often come in the form of fixed rates depending on the measures deployed.

As highlighted above (Figure 4), EE programs can be a cost-effective approach to engaging customers and achieving energy savings. However, traditional EE programs targeting LI customers are not as cost effective, and between 2009 and 2015 just 9% of total EE funding in the U.S. went towards LI customers [39]. To equitably achieve building decarbonization goals and provide marginalized customer opportunities to benefit, innovative customer programs are needed to improve cost effectiveness and to increase customer access to funding.

Energy service companies (ESCOs) have taken advantage of the business case associated with energy efficiency and decarbonization, and the growing demand from customers to offer services which enhance energy efficiency, reduce emissions, and reduce energy costs. The business models can arrange financing for projects and provide customers with the opportunity to offload the risks associated with investing in technology and efficiency measures. Some relevant business models which could impact equitable decarbonization include [40]:

- **The Energy Performance Contracting (EPC)** model enables ESCOs to invest or finance technologies that result in energy savings compared to a predefined baseline. Renumeration is performance-based in relation to the savings achieved, mostly found in the public, industrial, and commercial building sectors as it is best suited to large projects with long payback periods. EPCs have been trialed in large residential buildings.
- **The Enhanced Energy Performance Contracting (EPC)** model aims to generate revenues from energy savings, as in the classic EPC model, but this approach also accounts for revenue generated via demand response services.
- **The Energy Supply Contracting (ESC)** model enables a utility or ESCO to invest in efficient energy supply systems in new and existing public, industrial, commercial, and large residential buildings. Remuneration is based on useful energy delivered, therefore incentivizing the installation of efficient energy supply systems.
- **The Integrated Energy Contracting (IEC)** model is a hybrid of ESC and EPC which combines two objectives, the reduction of energy demand through the implementation of energy efficiency measures, and the efficient supply of useful energy demand, preferably from renewable energy sources. In the IEC model the utility or ESCO invests in technology measures, eliminating the technical and economic risk on the building owner, enabling cus-

tomers to buy services instead of the individual components. IEC can be applied in residential, commercial and public buildings, with remuneration for the investor coming via rates for useful energy consumed, for the capital cost of measures, and for ongoing maintenance of deployed technologies.

In summary, ESCO business models leverage performance-based contracting methodology and focus on investments in large buildings where energy consumption can be controlled and savings more predictable. These models can provide opportunities for utilities to learn and enhance customer program offerings by adapting existing programs or by working in tandem with ESCOs as service providers [41] [42]. While the EPC model can require strong baselines and accurate measurement and verification (M&V), the IEC model can potentially avoid or reduce high M&V efforts, and the ESC model could provide a simple and robust option when focusing on renewable technology deployment. The emerging on-bill models, which will be discussed below can present an alternative option for equitable decarbonization in customer segments where traditional ESCO models reach their limitations, such as in single family residential [43] [44].

On-tax models, like the Property Assessed Clean Energy (PACE) program were first implemented in 2008 to provide property owners with financing for energy renovation upgrades. Financial institutions provide funds, which are secured by the property itself and is repaid as an additional line item on recurring property tax bills (Figure 5). With repayment attached to the property being improved rather than to the individual who owns the property, and recourse for non-payment is the same as not paying a property tax bill. This model's implementation limits access to property owners, and in the past has been scrutinized for lacking quality control and oversight which could be addressed through the provision of more rigorous project screening, approval and tracking mechanisms [45].

Figure 5. PACE financing conceptual overview [45]

On-rent models enable building owners who do not occupy the property themselves, including housing corporations, government housing associations, or individuals who rent out their properties to cover the cost of investments for energy efficiency measures by increasing the tenants' rent by an amount equivalent to the energy savings (Figure 6). Alternatively, if the existing rental rate included energy bills this rental rate can be maintained. In this arrangement the property owners can seek out rebate opportunities and financing for the remainder of the upfront costs, this allows tenants to benefit from the deployed technologies without changing their cost of living negatively [46]. The on-rent model can offer a solution to the split incentive challenge; however, implementation of the on-rent model can depend on a suitable regulatory environment and the viability could be challenged if rental restrictions are in place such as with affordable or social housing.

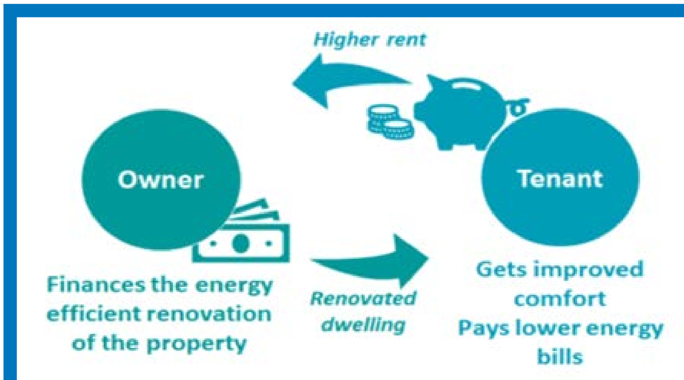

Figure 6. Overview of the On-Rent model [46]

Emerging Financing Models and Engagement Approaches

Engaging marginalized customers and ensuring their access to the benefits of decarbonization will require innovative funding models and cooperation among several stakeholders with a diverse array of technical expertise. These models can be offered by utilities, ESCOs, governments, local authorities, financial institutions, or non-profits. The following section outlines innovative financing models and engagement approaches that have emerged to address challenges of equity, affordability, and accessibility associated with traditional building decarbonization programs.

On-Bill Models

On-bill models allow customers to access finance and repay the upfront cost of technologies and efficiency measures through their energy bills over time. This model has shown significant potential to advance decarbonization and energy efficiency and equity in the residential sector, with two main categories, On-Bill Financing (OBF), and On-Bill Repayment (OBR) [47]. The difference between the two depends on the source of the funding which covers the up-front costs, with the specific repayment mechanism offered determining if the funding is treated as a debt to the customer [40], as illustrated in Figure 7.

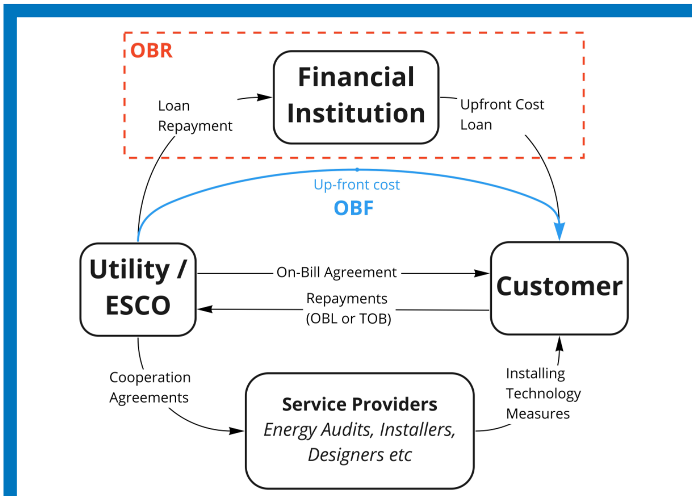

Figure 7. Overview of On-Bill models

On-Bill Financing (OBF): Through this method, a utility or ESCO provides a service which covers the upfront cost of implementing renewable energy and efficiency projects using its own capital and/or available public funds. Technology measures are usually approved and verified with pre-and post-install energy audits.

On-Bill Repayment (OBR): This is an arrangement where a utility or ESCO provides the service, with a financing institution and/or investor providing the funds for the technology measures. Repayment is collected as a part of the monthly utility bill. It differs from OBF in that neither the utility nor its ratepayers provide the capital [40].

The repayment mechanisms for OBF and OBR could be applied as follows:

On-Bill Loan (OBL): In this approach the funding takes the form of a loan which is treated as a debt to the customer. While usually capped with interest rates as low as zero interest, customers can require a qualifying credit score to access funding. The utility bill provides the tool for repayment of that loan with repayment tied to the customer, and repayment holds equal priority to the energy charge meaning failure to make repayments may result in energy service disconnection.

Examples of an OBR program with OBL repayment include the home energy efficiency loans offered by Craft3, a non-profit community development financial institution, in partnership with local government and utilities in Oregon and Washington. Eligibility requirements include owner-occupied single-family homes, suitable utility bill payment history, and a minimum credit score [48]. Idaho Falls Power also offers an Energy Efficiency Loan Program which includes a zero-interest OBL repayment to qualifying customers who install energy efficient technologies in their home [49].

Tariff-On-Bill (TOB): Also known as Tariff-Based Recovery (TBR) or Pay as You Save (PAYS) [19], in this approach investment is recognized as a system reliability investment for the utility and tied to the meter of the property. TOB enables the utility to add a tariff to the customer's meter, the monthly repayment charge is always lower than the estimated savings of installed measures and remains on the bill for that location until all costs are recovered (i.e., 'Bill Neutrality' or 'The Golden Rule'). This allows for repayment over time, but unlike a loan it is not classed as a debt to the customer and the payment obligation ends when occupancy ends or the measure fails, enabling transfer between tenants or owners. Depending upon program structure repayment failure could lead to service disconnection.

Examples of TOB customer programs can be seen in 18 US utilities in 8 states [45]. Evergy provides a TOB program, paying for cost-effective energy efficient technologies for eligible Missouri residential homeowners and renters (with owner consent). The upfront cost of eligible technologies will be covered as long as estimated savings cover at least 80% of the upfront cost over 12 years. Evergy recovers these costs through a fixed monthly tariff on the utility bill that is less than the estimated monthly savings [50]. Slipstream, formerly the Wisconsin-based Energy Center, outlines best practices for TOB (referred to as PAYS) programs that reduces risk for both the customer and utility [51]:

- The utility's cost recovery is calculated to yield a cash-positive result for tenants while eliminating or significantly reducing a landlord's up-front contribution.
- The tariff charge is limited to 80% of the participant's expected annual energy bill savings and the payment term cannot exceed 80% of the expected lifetime of installed measures.
- The establishment of a team of pre-qualified contractors trained and experienced in the program process to streamline the costs and implementation of home energy retrofits and to ensure retrofit quality.
- Analyses of participant billing data one year after the retrofit to identify outliers and enable follow-ups to identify and correct any issues that may be attributable to flawed workmanship.

On-bill programs that do not attach debt to the individual and enable transferability, such as the TOB model, are recommended as it can overcome challenges with customer reluctancy to take on debt for investing in energy efficiency and can provide a solution to the split incentive challenge. Basing program eligibility on an assessment of energy saving potential potential rather than a customers' economic status can also improve access to finance for energy efficiency improvements for lower income groups as well as small and middle-sized enterprise [52].

Rewarding customers for regular payback on utility bills is another emerging concept that could allow LI customers to bypass traditional credit score eligibility requirements, as good payment habits can be reflected in their credit score. These programs require special partnerships to be established between credit tracking agencies and finance institutions. While the possibility of service disconnection can raise concerns over social acceptance, on-bill programs with this clause included have been shown to reduce default rates to below 3%, compared to up to 15% for unsecured financing [40].

Case Study: Energy Efficiency as a Service, Seattle City Light

The Seattle City Light Energy Efficiency as a Service (EEaS) Program was designed to encourage deep retrofits in existing buildings and high-performance design in new construction by creating a monthly on-bill transaction mechanism that quantifies and returns the value of energy efficiency savings to the party responsible for making the investment (developer).

This program grew from a pilot demonstration of the Metered Energy Efficiency Transaction Structure (MEETS) mode [53] at the Bullitt Center [54] in Seattle. EEaS is designed to overcome the split incentive hurdle in commercial buildings, where the financial benefit from the energy retrofit is not realized by the capital investor. Customers can upgrade their building at no upfront cost by effectively funding improvements over time through their energy bills. SCL facilitates the transaction by adding an energy efficiency (EE) service fee to the end user's utility bill. A third-party metering entity measures the energy usage against a dynamic baseline model to calculate the savings in energy units. The savings are added to the customer bill at a separate rate that is predetermined in the energy user's participation agreement (PA) and is designed to result in an EE service fee which enables 'bill neutrality' (see Figure 8). SCL then pays the developer via a Power Purchase Agreement (PPA).

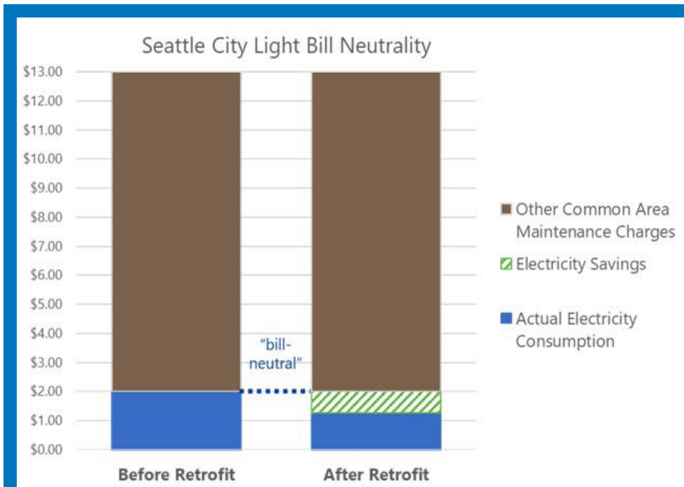

Figure 8. Energy users stays "Bill-Neutral" Source: Seattle City Light, September 21, 2020

The agreement terms can be up to 20 years from time of signature. EE Fees and PPA Payments commence upon beginning of performance period. The PA and PPA are contingent upon each other, meaning one cannot be active without the other. If the building owner sells the property before the end of the payment period, the seller must transfer the PA to the buyer. If the PPA is terminated in the first 5 years, the EE developer may receive incentive from SCL, unless the PPA payments are already paid. Eligibility criteria include:

Customers:

- Owner/tenant where split incentive is present
  - Building is at least 75% occupied
  - Conditioned area is greater than 50,000 square feet

- Primary utility account is a commercial rate code and accounts for more than 90% of the building's electricity consumption
- Existing Buildings:
  - Must have 12 months of energy consumption history to create baseline
  - Must achieve >25% energy savings against baseline
  - Weather/occupancy must be an accurate predictor of energy consumption
- New Buildings:
  - Must Select Target Performance Path (C401) as compliance pathway for Seattle Energy Code
  - >25% savings compared to Seattle Energy Code Target Performance Path (TPP).
  - Electricity is sole fuel source for all end-uses
  - Primary use types: Office, Medical Office, Retail

From a utility perspective, other than managing the program logistics and coordinating with a neutral third party, a key challenge is capturing the energy savings accurately. As such SCL has replaced customer meters with advance metering infrastructure (AMI) to obtain accurate interval data and ensure more accurate savings calculations. The minimum requirement for participation is a 25% annual savings forecast, and the customer is not billed until 10% savings are achieved. This provides a safety net for SCL and encourages the developer to move quickly. SCL has reported difficulties in identifying eligible customers due to the requirement for 90% of energy use to come from one customer who is not the building owner. This ultimately disallows them from targeting owner-occupied commercial buildings [55].

Case Study: Green Deal Program in the UK

The main difference between the European and American customer programs is the active role taken by the government in European programs [40]. In 2009, the UK implemented the Green Deal program, the first on-bill policy in Europe. The financial mechanism followed the TOB model with loans from an accredited provider covering the building refurbishment costs, with a tariff attached to the utility meter and repayments made by the customer, the utility then paid the collected tariff money to the third-party creditor. Many hypothesized that the main barrier to energy retrofits was the upfront cost so it was anticipated that the Green Deal program would lead to 14 million retrofits by 2020. However, just 14,000 homes were retrofitted by 2016 when the program was discontinued. There are numerous reasons for this failure:

- **Limited Financial Appeal:** The 7% interest rate offered was higher than market value for secured (3.5%) and unsecured (6-7%) loans, due in part to the option to avoid any public subsidies for the program.
- **Poor program design:** There was low customer interest in joining the program as the high interest rates limited the types of measures that could be implemented.
- **Low level of engagement with consumers:** The Green Deal program was marketed as a financial mechanism, and emphasis was mostly placed on the assistance for upfront investment. While this is important, other non-economic energy benefits such as improvement in home comfort or health benefits were not emphasized, despite evidence that these benefits play an important role in increasing public support [56].
- **Complex bureaucratic procedures:** Joining the Green Deal program entailed a complex process involving numerous third parties such as energy assessors, advisors, service providers, and installers without a single effective coordinator. The lack of coordination among parties discouraged program engagement. In addition, the program was often not the primary focus of the parties involved, further hindering the program.

Case Study: Applying On-Bill Models in European Utilities

The European Commission funded project RenOnBill worked with European utilities to develop on-bill programs to better understand their role in scaling up investments in residential building energy renovations. To do this the team developed the ERV-Tool with the goal of improving a utilities ability to accurately estimate energy savings when considering large investments in residential energy renovations [57].

The ERV-Tool conducts engineering, financial, and risk analyses using a probabilistic and integrated approach oriented towards the analyses of multiple projects or a segment of a particular housing stock. The tool aims to assist utilities in the evaluation and bundling of energy efficiency investments in the residential sector to design and implement on-bill programs that reduce upfront costs for customers [53]. This tool was tested by three utilities. Table 1 highlights each utilities' experience in determining the most suitable customer, buildings, and measures to target with on-bill programs.

Table 1. Summary of 3 European utilities' design and application of On-Bill schemes

	Spain - Fenie Energia	Lithuania – AB Kauno Energija	Italy - Bluenergy Group
Utility Description	Publicly owned electric utility	District heating (DH) utility, originally from gas, now 90% green (biomass) supplying heat to > 120,000 homes and 3,500 businesses	Gas and electric utility with > 250,000 customers
Utility Motivation	• Address energy efficiency government mandates • Gain new customers • Increase customer loyalty and trust • Improve position as cutting-edge utility with sustainable image.	• Opportunity for utility to generate new revenues from system investments • Gain access to new customers • Improve existing customers loyalty • To have environmentally friendly and socially inclusive business.	• To take advantage of existing government incentives and increasing customer interest • To offer a new One-Stop-Shop (OSS) service to expand business and customer base.
Targeted Customers	Owners of homes/apartments	Owners and renters in multifamily buildings	Apartment owners or multifamily building owners/administrators
Targeted Buildings	Old 1920's era urban community and a 1970's era rural village	> 2,000 pre-1992 inefficient multifamily buildings with old and inefficient DH equipment.	Targeting 100 Inefficient multifamily buildings with central heating, built between 1961 and 1975.
Key Measures Identified	PV, windows, Heat Pumps, lighting	Replacing gas DH boilers with electric HPs	Insulation, and central heat system renovation (HPs), with additional optional measures like seismic improvements, smart home features and EV charging
Results Summary	The utility offers energy renovation services built on the on-bill approach, with the utility sourcing financing, and the customer making re-payments on bill. The designed packages piloted were estimated to have a positive cash flow by year 11, with 18-year payback period for the utility. Overall, at end of 2-year pilot phase, 50 dwellings were renovated with 3,500,000 kWh and €65,000 saved.	While strong interest in the concept, the utility faced challenges with implementation including a lack of personnel with expertise in HVAC renovation design, difficulty engaging and informing end users in multifamily building, and slow decision making with a majority vote amongst residents required. Financially smaller measures did not make sense, and the low cost of DH supply has lowered interest in renovation. It is suggested that government incentives, equivalent to 20-40% of upfront cost would be a key factor in improving cost effectiveness on utility to enable implementation of an on-bill service offering.	OSS approach taken with the utility supporting and coordinating implementors. Strong government incentives available which cover all upfront costs of eligible measures, allowing for a minimum contribution from customers on-bill. 100 buildings with over €115 Million in project value identified, so far €8 M completed. With incentives expected to reduce in coming years it is expected that the on-bill business model will remain viable with a slightly higher customer on-bill contribution.

The One-Stop-Shop Concept

The One-Stop-Shop (OSS) concept, also known as Integrated Home Renovation Services (IHRS), is a both a business and customer engagement model for applying the innovative financing models outlined above. The OSS aims to bring together into one place all of the technical and economic assistance customers need when undergoing an energy renovation. Increasing customer access to information, incentives, financing, and quality contractors. OSS often involves coordination between stakeholders such as utilities, ESCOs, financial institutions, contractors and installers, OEMs, local governments, and community organizations. As indicated in Figure 9, there are 3 main models for OSS/IHRS [59]:

The Advice model focuses on baseline customer engagement, namely the initial customer advising process. This may include identifying prospective customers and advising on financing opportunities and selecting contractors or financial institutions.

The Support model focuses on supporting homeowners in the design of energy renovation projects, and can include support with project screening/identification, company/contractor selection, price negotiation, worksite supervision, quality assurance, and post-installation follow-up. In this model, the OSS provider is fully engaged and assumes liability for the support provided.

The Implementation model provides detailed advice and designs retrofit packages, while also implementing all or part of the renovation work. In this model, the OSS provider has an economic interest in delivering the planned work and selects the contractors and companies involved. The OSS may profit or charge a fee for providing the service, while also assuring quality and retrofit performance or energy savings.

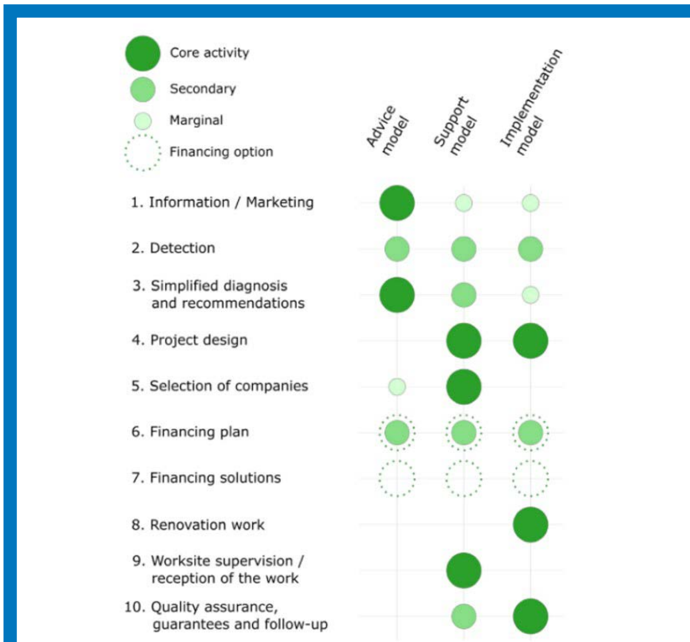

Figure 9. Overview of the main OSS/IHRS. Models [59]

The boundaries between these three models can blur depending on the stakeholders involved and the unique approach taken. All three models can provide the option of a suitable financial plan and mechanisms for repayment. Whether following an Advice, Support, or Implementation model, the engagement strategy of an OSS can vary. Examples include [60]:

- **An OSS provided by a multi-disciplinary team**, where partners with complementary competencies work cooperatively, such as architects and designers, constructors, energy-efficiency experts, market and financial experts, technology suppliers, operations planners, and financial institutions. This usually follows an implementation model, taking full control of design and deployment. Examples include Energiesprong [61].
- **An OSS supported by a Step-by-Step approach** creates a bespoke building renovation plan to help customers make upgrades at the most optimal time depending on the state of their existing technologies. This spreads investment out over time. An example would be iBRoad [62].
- **An OSS supported by digital tools** can streamline customer enrolment and provide suggested renovation plans with estimates of the costs and energy savings based on information about the current building and the needs, objectives, and resources of the building owner. This approach relies on the quality of the information provided as well as information on the local building stock to support the initial design and planning of the renovation. Examples include the RenOnBill tool [57], BetterHome [63], and XeroHome [64].
- **An OSS provided as complementary business by utilities** requires utilities to provide holistic renovation services to customers. This includes advising and supporting the design, implementation, and financing of suitable cost-effective technology measures. For utilities in competitive supplier markets like Europe, this offering can attract new customers. For utilities in general, the OSS model is a means to deepen customer engagement, increase customer trust, end-use efficiency, flexible load availability, and opportunities for new revenue streams. Examples include Energieheld (Switzerland), EDF (France), Superhomes [65] (Ireland), Bluenergy (Italy).

The distinct characteristics of these examples can be adapted selectively depending on the project or program need. For instance, a utility could provide a complementary business offering, leveraging a multi-disciplinary team and digital tools to plan a step-by-step renovation for customers. The key benefit of OSS services is the ability to provide a single point of contact and make it easier for marginalized and disadvantaged communities to access the finance and expertise required to plan, coordinate, and implement a cost-effective home energy renovation.

Most OSS models will entail significant multi-stakeholder cooperation, with models leveraging digital tools offering the potential to streamline and accelerate customer enrollment, program coordination, and retrofit package design and evaluation, while helping to reduce program set-up and operational costs. The case study discussed previously on the TOB style Green Deal Program in the UK has also highlighted several learnings that could aid in the success of an equitable home energy renovation OSS program. These include the importance of competitive interest rates, an effective program coordinator, dedicated retrofit teams, a simple enrolment process, and an engagement and marketing approach that highlights all customer benefits not just financial.

Case Study: The Energiesprong Approach

Energiesprong aims to enable a self-sustaining market for the rapid deployment of net-zero energy home renovations where residents have no upfront costs and benefit from a more comfortable, attractive, and valuable home while maintaining their cost of living. Customers are engaged through an OSS with an innovative financing model that combines elements of on-bill, on-rent and EPC models, where the net present value of the lifetime energy cost savings covers the upfront costs. Residents of social and affordable housing can repay investments over time via an 'Energy Service Plan' which replaces previous energy and rental bills (Figure 10) [61].

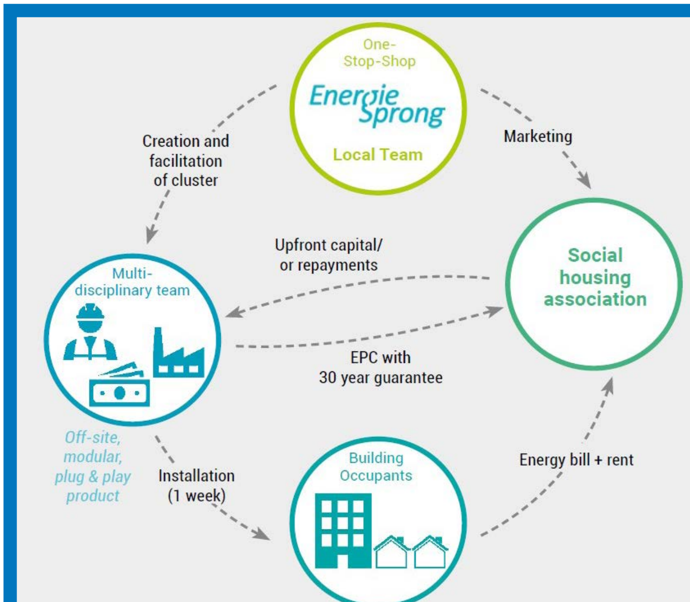

Figure 10. Overview of the Energiesprong approach [60]

To make this model feasible in the residential sector, the Energiesprong approach depends on an integrated and industrialized supply chain to streamline the retrofit process. The approach focuses on social or affordable housing associations with large stocks of single or multifamily homes with similar designs. Renovation packages include the installation and production of solar panels, electric heating and cooling, and external insulated facades. A 30-year energy performance guarantee of each retrofit package backed by an insurer enabling the energy savings to finance the upfront costs. It is hoped that overtime, this approach will reduce costs and ensure the standardization and quality of retrofits, which will allow a one-week install time and no upfront costs for residents.

Over the last 5 years, Energiesprong have renovated 5,700 homes in the Netherlands, with 100,000 currently planned. Various programs inspired by Energiesprong are underway in New York (RetrofitNY) and California (REALIZE), as well as in France, the UK, Germany, and Italy.

Led by the Rocky Mountain Institute (RMI) and funded by the US Department of Energy, the California Energy Commission, and philanthropic sources, REALIZE seeks to establish high-volume net zero carbon retrofit delivery programs in California and Massachusetts. Market facilitation activities include aggregating retrofit demand while coordinating the supply chain to deploy high-quality, prefabricated retrofit packages that are easy to install, and financed through utility cost-savings [66].

REALIZE is launching several pilots to demonstrate a highly integrated retrofit deployment process across the multifamily housing market. An example retrofit package includes prefabricated façade panels, electric heating and cooling, insulated roof panels with solar panels, and all electric appliances.

In New York, NYSERDA are leading the state funded RetrofitNY program, with the initial focus on affordable multifamily buildings with the goal of lowering value chain costs through innovative business models conducive to scaling energy retrofits. Currently the team are building a pool of candidates which include building owners, component manufacturers, and solution providers. Where the solution providers will work directly with building owners to deliver whole-building energy retrofits, with funding for eligible candidates expected to be in the range of $100k for project design plus $40k per unit.

While Energiesprong and its spin offs are promising models that may help address equity issues in residential building decarbonization, further time and assessment is necessary to determine whether these approaches will be self-sustaining and cost effective in the long run [67].

Case Study: Analysis of European One-Stop-Shops for Home Energy Renovations

An analysis of 34 existing and 6 terminated OSS in Europe found that, successful cases generally applied a model that fully supported customers through the entire process [68]. Of the OSS initiatives studied, 19 were public initiatives, while just 7 were exclusively private partnerships, with public entities mainly consisting of local town councils. Half of the OSS studied deploy a 'Support' model, 26% operate with an 'Advice' model, 24% with a coordination style model that falls between 'Advice' and 'Support', and 3% had a full 'implementation' style model offered by an ESCO. In countries with a higher GDP, the most predominant models fall under the 'Support' and 'Implementation' range due to the level of facilitation provided to customers.

Most of the OSS examined began as pilot projects and received public financing through EU programs to cover operating costs. Many of the OSS also charge customers for the service provided, with the view that the OSS could become self-sustaining over time. Among OSS that were unexpectedly terminated, activities often ceased due to a lack of structural funding. Only 16% of OSS use public financing to fund the actual retrofits, ESCOs that provided an OSS generally profited by leveraging private financing to fund renovation works. Key benefits of successful OSS include [68]:

- Financing and energy savings guarantees, which help individuals make renovations decisions.
- Bringing together fragmented market suppliers such as utilities, OEMs, installers, contractors, and financial institutions.
- Providing customers with a single point of contact.

In summary, while implementing an OSS can be challenging from a financial and operational standpoint and requires strong public support. The 'Support' and 'Implementation' models can unify several market players, helping to accelerate home energy renovations.

Energy Community Initiatives

Energy Community Initiatives (ECI) organize and support decarbonization while increasing the agency of individual community members and democratic decision-making within the energy system. By increasing involvement in the energy system, community initiatives can decrease inequities by shifting focus towards local issues and incorporating community values into decision-making. In Europe, citizen engagement in ECI has increased in recent years. In 2021, it was reported that 7,700 energy communities existed with around 2 million European citizens involved [69].

Research has shown that ECI can unlock financing and private investment for renewable energy technologies, while improving public acceptance, customer trust, social inclusion, and sense of community [70]. For example, crowdfunding can enable a lower per-person investment and greater purchasing power. ECIs provide direct customer benefits with increased energy efficiency and lower energy bills. Broader societal benefits also arise from the democratization of access to energy markets and decarbonization of energy use [71] such as, greater local energy system resilience, and increased local economic benefits by creating diversified revenue streams and boosting local green jobs [72] [73] [74]. ECI's can also benefit power systems through increased self-consumption of energy generation which can reduce transmission losses, and through the provision of flexibility services from distributed energy resources (DER) for aiding grid management. ECIs can take on various governance models and legal structures which can include [75]:

- **Energy Cooperative:** Citizens jointly own and participate in renewable energy or energy efficiency projects. This type of ownership is the most common and primarily benefits its members, with distribution of profits limited and surpluses reinvested to support its members and/or the community.
- **Limited Partnerships:** This model allows citizens and communities to distribute responsibilities and generate profits by partnering with a private company. Governance is usually based on the value of each partner's share and may not always provide one vote to one member like in the cooperative model.
- **Community Trusts and Foundations:** The objective of such models is to generate social value and local development rather than benefits for local members. Profits are used to benefit community as a whole, so even citizens who do not have the means to invest in projects can benefit.
- **Non-profit Customer-Owned:** A legal structure where profits are returned to members, similar to a cooperative model. This can be used by communities that deal with the management of independent grid networks, such as community district heating networks. With organisations often collaborating with philanthropic, local charitable non-profits, and local government councils to support disadvantaged communities to advance energy equity.
- **Public-Private Partnerships:** Local authorities can decide to enter into agreements with citizen and community groups and businesses in order to ensure energy provision of projects and other benefits for a community.

A European Consumer & Citizen Engagement Working Group review of currently used organisation models for ECIs concluded that a transparent, trust-worthy and democratic governance model was required for substantial engagement of a citizen group, and the cooperative model most frequently achieved this [76]. A review of 24 case studies of ECIs in Europe found that the most common driver for engagement in ECIs is the motivation to invest in clean energy infrastructure for the community (Figure 11) [75]. The European federation of citizen energy cooperatives, REScoop.eu, is a growing network of around 1,900 such cooperatives serving around 1.25 million citizens [69] [77]. While in the U.S. electric cooperative utilities serve 42 million people, covering 92% of persistent poverty counties [78].

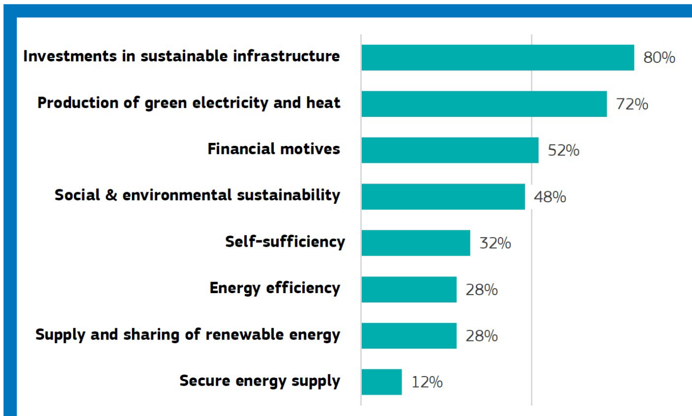

Figure 11. Drivers motivating engagement in European energy communities [75]

Non-profit ECI models can help to advance energy equity and affordability in a community beyond the development of renewable energy and efficiency projects. By providing an array of programs and services which can help with community engagement, outreach, and education, enabling community members to access energy renovation services or workforce development programs. For example, Green Spaces is a non-profit community owned organisation which aims to build an economically, socially, and environmentally sustainable community in Chattanooga, Tennessee [79]. Through partnerships with the local city council, Green Spaces programs achievements include the development of 17 solar PV arrays and 350 home energy renovations, while helping over 3,000 residents to reduce energy costs.

In Scotland the community trust model is the preferred structure for community energy projects, the community group is usually the full owner and raises funds through grants and loans and distributes income to the whole community. An analysis of privately owned and community owned (community trust model) wind generation projects in Scotland examined the benefits to the local community from both ownership models. An industry standard community benefit payment of £5,000 per MW per year was followed by privately owned wind famers, while community owned wind farms resulted in an average of £170,000 per MW in community benefit payments annually [80].

Demand Response (DR) and Time-of-Use (ToU) Rates

DR and TOU are other important enabling mechanisms for managing peak load challenges and improving the cost savings potential from electrification by providing new revenue streams to reduce energy costs. Connective grid-edge devices help customers access flexibility markets and services and manage energy use for ToU rates.

For example, EPRI worked with Ohmconnect, a demand aggregator to enroll residents into a customized behavioral demand response program that incorporated TOU-related messaging and behavioral energy savings tips into its day-ahead and day-of notifications. All the project's energy and demand savings reductions are entirely the result of behavioral changes, customers save on their utility bills, and can earn cash from improving on their baseline. When a notification is received that it is time to power down, results are rewarded with points that are redeemable in cash, gift cards, or free devices. Revenue is earned from the Demand Response Auction Market (DRAM) and is used to pay the end-user and the implementer.

Around 20 of 60 residents at an affordable multifamily property in Southern California successfully enrolled in the behavioral TOU demand response program. Performance data suggests that residents actively engaged, and that monetary and gamification mechanisms were motivating factors for participation. Sampled residents participated in at least 50% of DR events and saved up to 50% compared to their historic baseline. Energy consumption in 2021 during the 4-9 TOU window fell by approximately 15% compared to the previous years [81].

Understanding the Customer Purchase Journey

EPRI conducted a national survey of over 1,500 homeowners and renters, aimed at understanding the home energy equipment purchase journey of limited income households. Some key findings included [83]:

- **Purchasing new cooling and heating equipment:** Equipment malfunction and the desire for a newer and better product were the top two purchasing drivers.
- **Researching a new heating and cooling technology purchase:** The majority of respondents used online searches followed by visiting a local store and asking friends and neighbors, with asking a contractor for advice also ranking highly. There was a lack of recognition of the role of utility websites as a resource for information on technology options. Customers put a high level of trust in advice provided by community members and local contractors, indicating the importance of leveraging contractors to provide quality advice on emerging technologies.
- **Purchasing a solar system:** 62% of respondents stated that they were very or unlikely to consider a solar system, for whom the top barrier was high upfront cost, and maintenance concerns.
- **Payment method preference:** On average, the credit card ranked highest as preferred payment method (with homeowners having an even higher preference than renters), this was followed by cash, monthly payments from store or manufacturer financing, and monthly payments on utility bills (with renters having higher preference for this option). While there was a high preference for using credit to purchase new equipment and interest in alternative finance options was low amongst the respondents, this may have been due to a lack of information or availability.

Comparative Assessment: Benefits and Challenges

We assessed the benefits and challenges associated with the traditional utility approaches to financing building decarbonization, as well as the emerging financing models and engagement approaches detailed above. The findings are summarized in the following tables, where green represents 'yes' and red represents 'no'.

Table 2. The benefits and challenges of traditional building decarbonization financing models

Benefits	**DI Programs**	**EE - Rebate Programs**	**Demand Response**	**On-Tax (PACE)**	**On-Rent**
No customer upfront costs	Green	Red	Red	Green	Green
Improves customer energy cost savings	Green	Green	Green	Green	Green
customers access non energy benefits such as enhanced building quality and comfort	Green	Green	Red	Green	Green
Cost effective for program implementor	Green	Green	Green	Green	Green
Reduces carbon emissions, energy consumption, and peak loads	Green	Green	Green	Green	Green
Possible to reach lower income customers and renters	Green	Red	Green	Red	Green
Challenges					
Only cost effective for program implementors when targeting smaller measures.	Green	Green	Red	Red	Red
Access difficult for low-income customers and renters	Green	Green	Red	Green	Green
Requires suitable regulatory landscape	Red	Red	Green	Green	Green
Lack of verification of the quality and performance of technology measures	Red	Red	Red	Green	Green

Table 3. The benefits and challenges of traditional ESCO performance-based business models

Benefits	**EPC**	**E-EPC**	**ESC**	**IEC**
Entire process is managed by one entity	[green]	[green]	[green]	[green]
Mobilizes private capital and involves financial institutions in energy efficiency markets	[green]	[green]	[green]	[green]
DR revenue is added benefit for customers, and provides greater demand flexibility for utilities	[red]	[green]	[red]	[red]
Performance based financial renumeration with verification of energy savings and performance of installed measures	[green]	[green]	[green]	[green]
Possible application in residential sector	[green]	[green]	[green]	[green]
'Deemed energy savings' approach which estimates savings based on historical performance of similar measures, leading to lower program operation costs	[red]	[red]	[red]	[green]
Customer offloads technical and economic responsibilities and risks	[green]	[green]	[green]	[green]
Challenges				
Usually limited to large investments in public, commercial, or large residential buildings	[green]	[green]	[green]	[red]
Complex organizational procedures and contractual arrangements	[green]	[green]	[green]	[green]
Depends on strong estimates of energy cost reduction	[green]	[green]	[green]	[red]
Better suited for targeting building owners, so hard to reach tenants directly	[green]	[green]	[green]	[green]
Automation or control of DR loads may be required	[red]	[red]	[green]	[green]
Limited to energy supply systems	[red]	[red]	[green]	[red]

While DI and EE programs have been effective at improving energy efficiency, as a standalone tool their limitations are clear when attempting to increase the adoption of deep energy efficiency and decarbonization retrofits in the residential sector. Similarly, DR programs do not address the up-front cost challenge if it exists, although they can offer customers an avenue for managing and reducing energy costs. Making DI, EE, and DR programs accessible for all customers provides a diverse array of options for improving energy efficiency and affordability, and when programs are stacked it can improve the repayment terms of financing through on-bill programs.

The on-rent model can offer a solution to the landlord-tenant-divide; however, implementation of the on-rent model can depend on a suitable regulatory environment. On-tax (PACE) models limits access to property owners. Both on-tax and on-rent models can leave the utilities out of the loop, meaning customers may have to seek out technical advice and contractors independently, and there can be a lack of oversight of retrofit performance and quality.

ESCO performance-based models have proven effective when targeting large energy users, and while they often reach their limitations when applied to the residential sector and do not adequately address the challenge of split incentives, the innovative models provide opportunities for utilities to learn and adapt for specific applications (as evidenced by the Seattle City Light EEaS program). The IEC model can potentially avoid or reduce high M&V efforts which shows promise for application in segments of the residential sector with standardised owner-occupied buildings and good data availability, and the ESC model could provide a simple and robust option when focusing on renewable technology deployment in residential communities.

Table 4. The benefits and challenges of the emerging on-bill financing models and repayment approaches

Benefits	**OBF**	**OBR**	**OBL**	**TOB**
Fully covers customer upfront costs	Green	Green	Green	Green
Improves customer energy cost savings, and customers access non energy benefits	Green	Green	Green	Green
Debt attached to utility meter and not to the customer	Green	Green	Red	Green
Repayment tariffs can be transferred	Green	Green	Red	Green
Can overcome split incentives	Green	Green	Red	Green
Suitable for lower income customers and renters	Green	Green	Red	Green
Does not require extensive credit checks (alternative methods like utility bill payment history can be leveraged)	Green	Green	Red	Green
Secure repayment mechanism (potential for service disconnection reduces default rates)	Green	Green	Green	Green
Possible to target large range of buildings and technology measures	Red	Green	Green	Green
Provides utilities a platform to enhance the utility-customer relationship, increase the customer base and can become an added source of revenue	Green	Green	Green	Green
Mobilizes private capital and involves financial institutions in energy efficiency markets	Red	Green	Green	Green
Challenges				
Risk of service disconnection can be drawback for customers	Green	Green	Green	Green
Requires utility investment making it difficult to finance large measures and hence is less scalable	Green	Red	Red	Red
Substantial cooperation amongst several stakeholders required to set up and manage	Green	Green	Green	Green
Difficulty covering program operational costs	Green	Red	Green	Green
Making customers aware of the value of potential savings, and providing support for comprehensive retrofits	Green	Green	Green	Green
Requires suitable regulatory landscape to adjust utility bill	Green	Green	Green	Green
Strong estimates of energy savings needed to ensure savings will exceed repayment costs	Green	Green	Green	Green
Risk of repayment default when transferring from one tenant to another	Green	Green	Red	Green

Table 5. The benefits and challenges of the different approaches to One-Stop-Shop services

	One-Stop-Shop Services			
Benefits	**Provided by a multi-disciplinary team**	**Taking a Step-by-Step approach**	**Supported by digital tools**	**Provided as added business by utilities**
Advises and supports	Red	Green	Green	Green
Supports and implements	Green	Red	Red	Red
Single coordinator and point of contact for customers	Green	Green	Green	Green
Customer offloads technical and economic responsibilities and risks	Green	Green	Green	Green
Covers upfront costs with various financial mechanisms (including on-bill)	Green	Green	Green	Green
Maximizes lifetime of existing building technologies to lower and disperse investments	Red	Green	Red	Red
Includes performance guarantees	Green	Red	Red	Red
Automated enrollment and design process	Red	Red	Green	Green
Digital tools can enable streamlining of processes by tracking customer satisfaction throughout retrofit journey	Red	Red	Green	Green
Utilities have greater influence over technologies deployed, quality of contractors used, and can verify performance of deployed measures	Red	Red	Red	Green
Provides utilities the chance to develop strong working relationships with a cross-sector of stakeholders	Red	Red	Green	Green
Opportunity to provide a new service for customers to increase existing customer satisfaction and attract new customers.	Green	Green	Green	Green
Challenges				
Substantial cooperation amongst several stakeholders required to set up and manage	Green	Green	Green	Green
Requires targeting a limited segmentation of building stock to standardize solutions	Green	Red	Red	Red
Usually more suited to homeowners or landlords willing to invest over a period of time, making it hard to reach renters directly	Red	Green	Red	Red
Reliable data on the existing building stock, and of the specific building required for accurate energy savings estimates	Red	Green	Green	Green
Requires team with strong technical knowledge to optimize retrofit designs and plans	Green	Green	Red	Green

On-bill programs can eliminate the upfront costs of building decarbonization for customers, improve energy affordability, and overcome the split incentives challenge while helping utilities to meet carbon reduction goals. However, a review carried out in 2011 of eight on-bill programs in the US found that participation rates were low at around 1% of customers in targeted markets [82]. It was indicated that - in practice - there are several challenges with maximizing the potential benefits of on-bill programs. The insights gained from EPRI's customer surveys and research [83] suggest that OBR programs with a TOB repayment approach offer the best combination of benefits to overcome the split incentive challenge, including:

- Covering the upfront cost while attaching debt to the building meter and not the customer.
- Customer's living costs are not increased, and energy affordability is improved in the long term.
- Enabling transferability of payments between tenants and owners.
- Providing alternatives to traditional credit checks, like using historic utility bill payments.
- Involving private capital and financial institutions in building decarbonization markets increases funding available and can help ensure long term sustainability and scalability of programs

However, it should be noted there is a need to provide customers with low or zero interest rates where possible. Applying on-bill financing models with additional OSS services will be a crucial tool in advancing building decarbonization. OSS services provide opportunities to engage customers in a coordinated and comprehensive manner, providing a single point of contact and making it easier for customers to access technical and financial advice, hence reducing the perceived complexity of undertaking a building renovation. The varying OSS structures highlighted in Table 5 can be adapted by utilities or program implementors to extract the combination of benefits which best suit a particular region, customer, or building segment.

When considering the learnings from case studies discussed previously and the target customers this paper focusses on, utilities should consider offering on-bill programs within an OSS service which leverages digital tools, in partnership with a financial institution and dedicated retrofit teams. This approach can improve the ease of customer enrollment, management, and retrofit design, which can reduce operational costs. The quality of retrofits can be assured, and customer feedback can be tracked to continually streamline processes to maximise efficiency of delivery and customer satisfaction. Program implementors can also consider including energy savings insurance (ESI) to provide performance guarantees and mitigate the risk of poor retrofit performance and increasing a customer's living costs.

Equitable Building Decarbonization Metrics

Metrics are essential for evaluating the success of programs and projects associated with building decarbonization. Inseparable from the transition to a decarbonized energy system are the vast social and economic implications of this shift. Given the deep interconnections between historical inequities and fossil fuel dependency, there is a growing call to make equity a centerpiece of this transformation. As such, addressing the longstanding racial and socioeconomic disparities in both the economy and energy system will be integral in enabling financing mechanisms and business models for building decarbonization.

While efforts to establish metrics for equitable decarbonization program and initiatives are still nascent, examples from recent energy justice scholarship suggest that metrics should account for the disparate impacts on consumers, workers, and local communities. Metrics are also critical for tracking disparities between different communities. Impacts can be disaggregated by income level, frontline community, age, medical status, employment status, geography (i.e., rural vs. urban), home ownership status, race, gender, ability/disability, and language spoken.

Those seeking to catalyze investment in building decarbonization through specific financing or business models often need strong estimations and validation of savings or value derived from proposed projects. The increasing prevalence of advanced metering infrastructure (AMI) is making it possible to verify energy savings and understand other impacts such as peak demand, time and location of energy savings, and impacts on specific customers. Along with energy savings, understanding the cost-effectiveness of a customer program can be key to understanding a program's success and sustainability in the long term. The key energy and cost metrics traditionally considered by utility and program administrators include:

- Energy and peak demand reductions:
  - Estimated average annual energy savings over the life of measures deployed (MWh)
  - Estimated average annual peak demand savings, total and by share of overall demand (MW, %)

- Cost effectiveness metrics:
  - Average annual incremental cost of energy savings over the lifetime of measures deployed ($/MWh), which includes total resource costs, total program delivery administration costs, and total cost of incentives.
  - Net Present Value (NPV), an assessment of return on investment over investment period ($)
  - Discounted payback period, the period of time it will take for the investment to be repaid, based on selected discount rate of investment (Years)
  - Internal rate of return (IRR) is the rate of return on investment over lifetime of investment period (%)

While the cost metrics above could be used to design equitable and cost-effective decarbonization programs and retrofit packages, they do not provide insight on the distribution of program benefits, energy affordability, or other facets of customer access, and broader environmental and socioeconomic impacts. Equity-related energy metrics have historically focused on cost (e.g., energy affordability), contemporary climate and energy policies and goals have begun to address the systemic and multidimensional facets of the energy transition. With this shift, there is a need for metrics that address the many economic, social, cultural, and environmental ramifications of the energy system. This section groups metrics in four different categories: Energy Access and Affordability, Social and Cultural Representation, Environmental and Public Health, and Labor and Economic Participation, with the aim of establishing a set of core metrics and corresponding actions for measuring and improving building decarbonization program and policy effectiveness.[1]

Energy Access and Affordability

For decades, household income relative to the area median income has served as the fundamental metric and eligibility criteria for energy assistance and low-income weatherization programs. More recently, energy burden, or the percentage of household income that goes towards energy bill payment has been adopted and evaluated more widely as a key metric, with thresholds established for assigning a status of high energy burden (> 6%) or energy poverty (> 10%). A recent EPRI review of utility commissions in the US with energy affordability programs or goals found that around 70% now use the energy burden metric [84]. More recent energy justice scholarship, however, reveals how economic burdens tied to energy consumption are not necessarily encapsulated. For example, energy poverty rates vary significantly based on different assumptions made relating to household energy expenditure. One of many complicating factors underlying energy affordability measurement is the subjectivity of data gathered in surveys: "The poor have lower individual expectations (or adaptive preferences), and that they may feel ashamed to admit their inability to satisfy certain necessities or to afford certain items" [85] [86]. Thus, exclusive use of energy burden as a measure of affordability may obscure disparities. This section aims to redress this discrepancy, Table 6 presents expanded metrics for evaluating energy access and affordability.

[1] Additional metrics can be found in the Appendix.

Table 6. Energy Access and Affordability metrics and corresponding actions

Metric Description	Corresponding Actions
Decrease in percentage of household income spent on fuel and electricity (i.e., energy burden) [87]	• Limit household energy bills to the percentage of gross income through direct bill assistance in the short term and building energy efficiency measures in the long term. • Ensure that the cost of electricity relative to household income does not differ across population • Fund and develop energy assistance and efficiency programs to reduce disparities and costs for low and middle-income community members • Establish Percentage of Income Payment Plan • Limit household energy bills to percentage of gross income
Decrease in percentage of residents living below the poverty line [87]	
Decrease in energy cost disparities by demographic	
Increase in customer cost savings in money saved, broken down by income groups, demographics, and fuel mix [87]	
Increase in number of interactions with customers regarding building decarbonization programs [87]	• Decouple revenue to ensure that assistance programs are well funded • Increase percentage of total investments that goes toward supporting disadvantaged communities • Focus energy efficiency programs on structural change instead of burdening frontline communities to change behavior • Establish utility TOB financing programs to lower barriers to financing energy efficiency projects • Identify ways to extend financing to customers with higher credit risk, including using bill payment history for access to on-bill programs • Ensure disadvantaged and renter communities benefit from energy use savings after program implementation • Ensure affordable multifamily programs meet the specific needs of multifamily properties, including low upfront costs, contractor choice, streamlined access to both common area and in-unit incentives, and alignment with other multifamily and affordable housing programs. • Shift entire energy assistance system away from annual fuel subsidies and towards clean energy assistance programs to provide long-term renewable energy and efficiency benefits
Increase in amount ($) and percent of financing, rebates, or other incentives accessed, broken down by demographic [87]	
Increase in share of customers with access to on-bill finance programs funding energy efficiency by demographic	
Increase in share of customers participating in on-bill finance programs, broken down by demographics	
Increase in percentage of eligible customers enrolled in an assistance or benefit program, disaggregated by demographic [87]	
Increase in share of households participating in demand response, broken down by demographics	• Make demand response programs available to households of all income levels and ensure renters have same opportunities as homeowners • Increase access to energy-management systems through assistance programs • Make demand response programs available to households of all income levels and ensure renters have same opportunities as homeowners
Increase in share of customers with access to renewable energy (including breakdown for access to distributed renewable energy, access to microgrids), broken down by demographic [87]	

Social and Cultural Representation

Procedural justice, essential for increasing energy equity, "requires that traditionally excluded groups, frontline communities, and those otherwise marginalized due to the energy system work with policymakers to co-create and co-design a fair process for inclusion in energy decision-making" [5]. Building a more inclusive decision-making process begins with ensuring that stakeholders are on equal footing by providing them with the skills and knowledge necessary to meaningfully participate. This may entail, for example, public education campaigns about decarbonization and how it may affect their community and providing public reports on the distribution of impacts of utility programs. Further, it is important that community members are not simply informed of decisions but are meaningfully involved in decision-making from the very beginning. Table 7 details actions and metrics to improve democratic decision-making across the energy system through community engagement.

Table 7. Social and Cultural Representation Metrics and Corresponding Actions

Metric Description	Corresponding Actions
Increase in appointments to local advisory boards and commissions that represent disadvantaged groups or areas subject to environmental injustice, reflecting the gender, racial, and class diversity of the community [87]	• Ensure all community outreach is communicated in all local languages • Invite all groups affected by decisions to contribute to all stages of the decision-making process • Report and provide analysis of inequities and disparate impacts of the utility's programs and services • Establish partnerships with grassroots groups and organizations already working on equity issues, particularly affordable housing, economic, and energy justice organizations as well as tenants' unions and labor unions.
Increase in racial, ethnic, class, gender, and geographic diversity of planning organization boards [87]	
Increase in number of meaningful partnerships with local community-based organizations	
Increase in percent of community members engaged in energy policy rule-making proceedings [87]	• Provide all parties with public reports demonstrating how communities benefit from energy efficiency and renewable energy programs, and all the material resources and knowledge needed to participate on an equal footing • Hold community planning and visioning workshops after regular working hours and in ADA accessible location, and meaningfully incorporate feedback into policies, rulemaking, and decisions. • Clearly communicate with communities, stakeholders, and employees about how decisions will be implemented • Ensure that customers have multiple mechanisms to meaningfully provide feedback to their utility • Communicate progress to all stakeholders and create feedback loop with community members to demonstrate how their input is being listened to and acted upon. • Develop diversity program enrollment campaigns • Develop mechanisms for collecting data and evaluating the progress of racial and economic equity
Decrease in decision-making disparities by demographic (percent of customers involved in decision-making about utility actions (including attendance of meetings), disaggregated by demographic)	
Increase in number of community planning and visioning workshops	
Increase in percent of community recommendations that were meaningfully incorporated into final energy rules, policies, and decisions [87]	
Increase in percent of utility actions and projects engaged in with prior consent and consultation with Indigenous communities [87]	
Increase in amount of compensation provided to community participants	• Compensate community participants, advocates, and experts for their consultation • Inform customers of all assistance programs and payment options on calls seeking help paying a bill • Allow consumers to have a choice in the utility company or in generation methods used by utility

Environmental and Public Health

Traditionally, the focus of EE programs has generally remained limited to energy use and peak demand. Understanding the effectiveness of building decarbonization, however, also requires tracking the impacts on carbon emissions and other pollutants. An ACEEE report found that 45% of states now include assessments of impacts on CO_2 emissions, with 18% including other air pollutants, and 27% including non-air-based emissions. Nonetheless, 41% of states do not include any assessment of environmental impacts [88]. Table 8 details the expanded equity metrics and corresponding actions that can be considered to address environmental and public health benefits.

Labor and Economic Participation

Economic justice extends far beyond the customer standpoint. Affordability and access, moreover, are highly impacted by employment opportunity, quality of work, and income level. In order to address these underlying systemic issues, it is critical to consider the variety of economic benefits or burdens experienced by communities as a result of building decarbonization. This includes making changes to ensure that local communities, particularly marginalized residents, are prioritized for hiring and worker training opportunities. Some examples of this include fair wages, employee benefits, collective bargaining rights, unionization, and apprenticeship programs. Further, economic equity is furthered through other forms of participation in the energy system, including through energy resources that are owned or controlled by the community. Expanding and improving the quality of various forms of participation are important for addressing the complexities of injustice within our energy system. Table 9 details labor and economic participation metrics and corresponding actions.

Table 8. Environmental and Public Health Metrics and Corresponding Actions

Metric Description	Corresponding Actions
Decrease in metric tons (MT) of criteria pollutants [87]	• Create community benefit agreements for projects with environmental justice concerns • Collect and report robust data on emissions • Reduction in reliance on bridge fuels such as gas plants • Reduction in the risks and exposure to priority environmental justice conditions for priority neighbourhoods • Consider externalities such as environmental and system benefits in the valuation of renewable energy projects • Define and set strong public health goals • Incorporate environmental justice criteria and priorities into zoning, land use planning, permitting policies, and development of new projects • Identify the community's priority environmental justice conditions and conduct a comprehensive environmental justice assessment
Decrease in GHG emissions in metric tons of CO_2 ($MTCO_2$) and GHG intensity ($MTCO_2$ /MWh) [87]	
Decrease in accident fatalities per energy produced by fuel chain [87]	
Decrease in population and pollution burden disparities, measured by race/ethnicity, geography and all customer groups [87]	
Decrease in EJSCREEN Environmental Indicators disparities, measured by race/ethnicity, geography and all customer groups [87]	

Table 9. Labor and Economic Participation Metrics and Corresponding Actions

Metric Description	Corresponding Actions
Increase in local energy generation in GWh generated per year [87]	• Provide opportunities for community ownership of renewable energy assets via energy community initiatives • Provide opportunities for renters take priority and receive economic benefits in local renewable energy and energy efficiency projects • Expand access to distributed generation and storage, including microgrids, net metering, community solar • Cooperate with non-utility owned ECI's and ensure ECI's operated by the utility maximize the community benefits, including increasing community control and expanding the opportunity to use community energy projects to accomplish social goals. • Expand net metering programs to customers who participate in offsite solar generation, such as community solar, through virtual net metering • Alleviate the up-front cost barrier to community shared energy programs through tariff-on-bill programs. • Establish a "solarize" program focused on adopting solar at the community scale through accelerated local outreach to help residents purchase solar in bulk, allowing for lower costs and increased participation [89]
Increase in percent of energy resources/ assets owned or controlled by the local community [87]	
Value ($) of energy assets owned by all customer groups [87]	
Increase in percent of workers employed by utility (directly or indirectly) that are part of a union	• Report detailed data and tracking of employment, including salaries, wages, promotions, and new hires, disaggregated by race, gender, income, income or census tract, and all other relevant determinants • Provide frontline communities access to high quality, high wage jobs in the renewable energy sector • Ensure that employed workforce is unionized • Ensure that direct and contracted employees earn at least a living wage based on their location, and have access to health insurance • Ensure equitable wages and benefits across genders and races • Ensure worker safety and protections, rights to meal breaks and rest periods, and universal labor rights including the right to organize in the workplace and collectively bargain • Fund green job education and workforce development programs that prioritize frontline and disadvantaged communities • Establish robust apprenticeship and pre-apprenticeship programs and pay programs participants high wages with benefits • Provide family-sustaining benefits including healthcare, dental, retirements, holidays and paid time off, other elements of a comprehensive benefits plan, childcare, paid family leave, and funding for safety equipment and protective clothing, • Create high road careers that are linked to the infrastructure development of local distributed generation • Prioritize hiring local workers • Establish requirements for a certain percentage of spending toward WMBEs (women and minority-owned businesses), notify them of utility business opportunities, and report on WMBE expenditures
Earned income growth by income-level percentile for full-time wage and salary workers and by all customers groups	
Growth in jobs and earnings by wage level and by all other customers groups [87]	
Direct annual jobs created in full-time equivalents (FTEs) by all customers groups [87]	
Labor wage impacts in direct job wages ($/ hour) by all customers groups [87]	
Decrease in income inequality "95/20" ratio (i.e., a comparison of those in the 95^{th} and 20^{th} percentile for income) [87]	
Decrease in Gini coefficient (i.e. income inequality) [87]	

Discussion and Conclusions

The case for decarbonizing buildings is clear: as a society we need to reduce carbon emissions to alleviate the impacts of climate change as inaction is likely to be much more costly in the long run [90]. Investments in building energy efficiency have proven they can be cost-effective for utilities via existing customer programs, although innovation is required to improve programs targeting lower income customers. ESCOs have well-established business models that can reduce the up-front costs and complexity of building energy renovations for customers. However, in general the performance-based business models applied by ESCOs target property owners of larger buildings where the energy savings and economics are more conducive to a clear business case. The integrated energy contracting (IEC) model shows strong potential benefits when applied to large stocks of residential buildings.

Utilities are well positioned to further bridge the gap between existing public and private initiatives to ensure the equitable distribution of building decarbonization benefits in the form of lowered energy costs and healthier more comfortable buildings for all. To do so, utility building decarbonization programs and financing offerings will need to address the known barriers to reaching marginalized customers. Namely, to overcome high upfront costs, engage hard to reach customers, and address the split incentive challenge.

Enabling equitable building decarbonization will also require an increase in the total funding that is available, and an increase in the accessibility of this funding for marginalized groups. The key strategy which addresses these challenges could be engaging customers via a one-stop-shop (OSS) style building decarbonization program that offers an on-bill repayment (OBR) program with a tariff-on-bill (TOB) repayment mechanism.

OBR programs with TOB repayment involve financial institutions which can increase investment in building decarbonization and energy efficiency, with competitive repayment terms with little to no interest rates, and a secure repayment mechanism that has proven to reduce default rates [40]. The TOB approach can address the upfront cost and split incentive challenges by attaching debt to the building meter and not the customer, which can enable transferability of payments. Customer access to financing can also be improved by providing alternatives to traditional credit checks, and by ensuring monthly repayment tariffs are equal to or less than the value of energy savings (i.e., bill-neutrality) living cost increases can be minimized.

While demonstrations of OSS models are nascent, their potential benefits are clear, they can provide opportunities for utilities to cooperate with a cross sector of expert stakeholders from local municipalities, community groups, or trade associations to offer customer-centric building decarbonization services which fully advise and support customers. An OSS models that leverages digital tools and a team of quality contractors could offer the potential to reduce operational costs, and to minimize the complexity of customer enrollment, management, and retrofit design at scale. Over time effective digital tools can help to streamline retrofit designs and estimates of energy savings.

The combination of an OSS with TOB can offer significant potential to increase equitable access to the benefits of building decarbonization, ensure the quality and performance of installed measures, and help utilities achieve broader carbon reduction and energy efficiency goals. However, this paper has highlighted several potential challenges with on-bill and OSS models that should be considered carefully when designing building decarbonization programs for specific regions, customers, and building segments. These include organizational challenges and administrative costs, the allocation of risk in the event of payment default, the complexities of implementing payment transfers, and ensuring energy savings exceed loan or tariff payments (i.e., need accurate estimates of savings).

Utilities can consider facilitating ECIs to offer OSS and TOB programs to decarbonize whole communities, working with existing community organizations to engage customers and improve public acceptance and trust in energy efficiency and renewable projects. ECIs based on the energy cooperative model can provide all engaged community members with an equal ownership share and vote on investments within a community, and this can be an important mechanism for decarbonizing buildings and advancing equity within the energy industry on a whole.

Equity in building decarbonization encompasses a wide array of issues such as community engagement, ownership of resources, energy affordability, environmental health, and fair workplace practices. Tracking and analyzing the social and economic characteristics of the energy system could be essential to ensure financing for building decarbonization results in equitable outcomes. The metrics and corresponding actions that are presented in this paper can be customized to the scope and circumstances of the program or utility initiative and the utility service territory.

For example, an expanded metric set may include increasing and tracking the program enrollment, participation, and performance among historically underrepresented groups. Another metric could be leveraged to track increasing social and cultural representation on program planning or advisory committees, so activities accurately reflect the needs of the service territory which is being served. On the topic of environmental and public health metrics, an inventory of appropriate metrics based on a site's environmental and public health history may be a starting place for establishing benchmark improvements beyond energy and demand and cost-effectiveness. On the labor and workforce participation side, metrics and requirements for decarbonization project implementation could include hiring locally among historically underrepresented groups and/or unions and extending local ownership for program investments. Demographic features that are tracked should be chosen thoughtfully by each program manager to reflect the composition of the region and community being served.

While this report offers a variety of suggestions for expanded energy equity metrics relating to building decarbonization, direct and comprehensive engagement with communities at the grassroots level can be essential for identifying specific issues and priorities at the community level. In the future, evaluation of building decarbonization programs may incorporate equity concerns by applying a wide variety of metrics through a comprehensive impact assessment methodology.

Appendix

Energy Access and Affordability (Continued)

Metric Description
Decrease in utility rate individual equity score: $e_{(i)} = ((a_i - \pi)/\tau_i)$ where e_i is the equity score, τ_i is the tailored rate, and a_i the actual rate paid by the customer. [91]

Environmental and Public Health (Continued)

Metric Description
Decrease in air pollution exposure index disparities, measured by race/ethnicity, geography and all customer groups [87]
Decrease in disparities of percent of adults with asthma measured by race/ethnicity, geography and all customer groups [87]
Decrease in disparities of EJSCREEN composite score for environmental vulnerability, measured race/ethnicity, geography and all customer groups [87]
Decrease in CalEnviroScreen Pollution Burden Indicators disparities, measured by race/ethnicity, geography and all customer groups [87]
Decrease in disparities of EJSCREEN composite score for demographic vulnerability, measured by race/ethnicity, geography and all customer groups [87]
Decrease in disparities of EJSCREEN Demographic Indicators, measured by race/ethnicity, geography and all customer groups [87]
Decrease in disparities of CalEnviroScreen Population Characteristics, measured by race/ethnicity, geography and all customer groups [87]

Labor and Economic Participation (Continued)

Metric Description
Average annual receipts per firm by all customers groups [87]
Number of firms by all customers groups [87]
Number of job trainees; job placements; and new hires retained after 2, 5, or x years – by all customer groups [87]
Percent of employees, by all customer groups, in mid-level and senior-level positions [87]
Decrease in percentage of women, men, children, and additional subgroups of residents living below the poverty line [87]
Increase in percent of energy resources/ assets owned or controlled by women and equity business enterprises [87]

Social and Cultural (Continued)

Metric Description
Increase in communication to customers regarding decision-making opportunities and progress updates regarding those activities, by demographic [87]
Increase in outreach (e.g., for education or input) to specific addresses, number and frequency of community meetings, frequency of 1:1 conversations, types and frequency of social media outreach, and which languages materials are translated into [87]
Increase in funding to help involve marginalized and vulnerable communities in rule-making proceedings [87]

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