WEP Warwick Evans Publishing

Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 9
GBMS 2024

Overcoming Financial Barriers to Eletrify HVAC in Commericial Buildings

Ziwei Xue

University of Virginia, Charlottesville, VA, the United States

Abstract. The electrification of heating, ventilation, and air conditioning (HVAC) systems in commercial buildings is essential for reducing energy consumption and greenhouse gas emissions. The U.S. Department of Energy's Commercial Buildings Integration program aims to cut energy use intensity by 30% by 2030 and achieve net-zero emissions by 2050. Despite these ambitious goals, commercial energy consumption has increased significantly from 2018 to 2022, underlining the urgent need for more effective efficiency measures. A major obstacle is the high upfront cost of efficient HVAC technologies. This study, conducted for the General Services Administration (GSA), explores three financial strategies to encourage HVAC electrification: On-Bill Financing (OBF), Asset-Backed Securities, and a Guarantee Facility Model. Among these, OBF, which ties repayments to utility savings, was found to be the most effective in addressing cost barriers and promoting equity. The study recommends that the GSA develop a comprehensive OBF program proposal, build on successful residential sector models, and launch campaigns to raise awareness. Future research should address data limitations and regional building code variations to better adapt policies to market needs.

Keywords: Energy Efficiency, HVAC, Climate Policy, Energy Financing, Building Electrification.

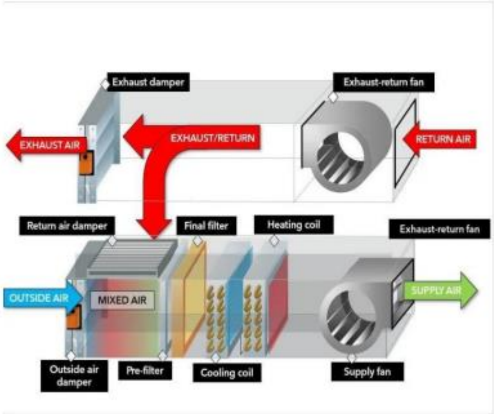
1. Introduction

1.1. Commercial Building Energy Emission

The U.S. commercial building sector faces the challenge of balancing energy demand with environmental responsibilities. Most recent commercial buildings energy consumption survey conducted by the Energy Information Administration (EIA) reveals that commercial buildings consume about 35% of national energy and are responsible for 16% total carbon emissions, making it imperative to transform the sector's energy profile [1]. In response, the U.S. Department of Energy (DOE) launched the Commercial Buildings Integration (CBI) program to reduce energy consumption and carbon emissions. The program aims to cut energy use intensity by 30% from 2010 levels by 2030 and achieve zero greenhouse gas emissions by 2050 [2].

However, energy consumption in commercial buildings rose from 6.8 quadrillion British thermal units (Btu) in 2018 to 9.6 quadrillion Btu in 2022 [1]. This increase not only boosts direct emissions from fossil fuel combustion but also amplifies indirect emissions from electricity use, which is predominantly generated from fossil fuels. Greenhouse gases like carbon dioxide, methane, and nitrous oxide significantly contribute to global warming by trapping heat [3]. Reports from the UN Environment Programme and the Intergovernmental Panel on Climate Change underscore the urgent need for intensified global efforts to combat climate change [4,5].

1.2. HVAC Electrification



By using advanced filtration and air handling processes, HVAC systems can precisely regulate temperature, humidity, and air purity. Adjustable dampers regulate the mix of outdoor and return air, which serves as the cornerstone of optimizing system efficiency [7]. Shown in Figure 1, a dual-stage filtration process—consisting of pre-filters and final filters—crucially maintains high indoor air quality by filtering out particles and contaminants. Meanwhile, heating and cooling coils ensure precise thermal control to meet desired temperature standard.

Figure 1: Electrified HVAC Operation Process [6]

A critical step towards enhancing building energy efficiency is the electrification of heating, ventilation, and air conditioning (HVAC) systems—replacing fossil fuel-based systems with electric alternatives. Implementing advanced HVAC technologies, particularly high-efficiency heat pumps, is essential. This upgrade not only improves thermal comfort but also significantly reduces energy consumption and greenhouse gas emissions. Transitioning to efficient electrified heat pumps could reduce emissions by 44% and energy use by 37% [8]. Air-source heat pumps consume about 50% less electricity than electric resistance heating and can outperform standard air conditioners in efficiency. Heat pump water heaters are two to three times more efficient than electric resistance models, and heat pump clothes dryers and induction cooktops also offer substantial energy savings [9,10,11].

1.3. Energy Efficiency Gap

The energy efficiency gap in the U.S. commercial building sector represents the difference between the optimal and actual levels of energy efficiency. This gap is driven by both financial and informational barriers. High initial investment costs for efficient HVAC technologies are a significant obstacle, particularly for smaller businesses or those in less affluent areas [12]. Additionally, the structure of the commercial real estate market can misalign costs and benefits, especially in lease arrangements where the investor in energy efficiency improvements does not directly benefit from the savings [13].

Uncertainty about return on investment (ROI) timelines adds complexity, as ROI can vary based on HVAC technology selection, current building efficiency, and energy market fluctuations [14]. Informational barriers further contribute to the efficiency gap, as building owners may lack knowledge about potential energy savings or distrust vendors' advice due to perceived sales motives [15,16,17].

To overcome these barriers, government intervention is necessary to create financing programs that make energy efficiency upgrades more affordable and accessible. Such programs would help businesses navigate financial and informational hurdles, thereby contributing to broader reductions in greenhouse gas emissions.

2. Literature Review

2.1. Common Existing Mechanism

In many U.S. localities, the Commercial Property Assessed Clean Energy (C-PACE) program is a key financing mechanism for energy improvements. C-PACE leverages private capital to provide upfront funding, which is repaid through special charges added to the property tax bill. Funding sources include private lenders, municipal bonds, and public funds, secured by a senior lien on the property [18,19]. This model integrates repayment seamlessly into the property owner's existing financial obligations, making it easier to manage and more appealing for investment. A notable example of C-PACE's impact is Milwaukee's financing of a $2.5 million investment in The Marlow Hotel, which is expected to nearly halve annual utility costs and save over 3 million kBTUs per year [20].

Another common financing mechanism is Energy Savings Performance Contracts (ESPCs). In this model, shown in Figure 2, an Energy Service Company (ESCO) installs energy-efficient equipment at no upfront cost to the property owner. The cost is recouped over time through energy savings, lowering utility bills and allocating a portion to repay the ESCO [21,22]. ESPCs are typically used by large facilities, such as government buildings or corporate properties, where the ESCO implements and maintains energy upgrades. These contracts often guarantee energy savings, reducing financial risk for the property owner, as the ESCO covers any shortfall [23].

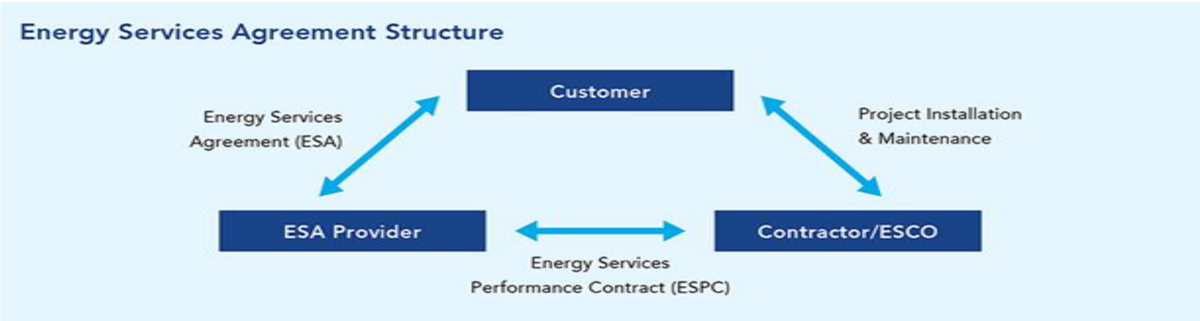


Figure 2: ESPC Model [24]

ESPCs are advantageous because they transfer the financial risk of energy-saving measures to the ESCO, incentivizing optimal system performance [25]. They also include long-term maintenance and operational services, ensuring equipment efficiency and longevity. ESPCs enable large-scale energy efficiency projects without affecting capital budgets, allowing property owners to upgrade facilities with the latest technologies [26].

2.2. Effective Financing Alternatives

2.2.1. On-Bill Financing

Within the residential building sector, On-Bill Financing (OBF) has become a key instrument in advancing energy efficiency measures. Demonstrating this expansion , in 2022, twenty-two states either enacted legislation or saw utilities take action to implement OBF for energy efficiency purposes. OBF enables homeowners to pay for energy upgrades through regular payments on their utility bills, with the premise that the energy savings from such upgrades will meet or exceed the repayment costs. This method has been associated with a reduction in loan default rates, suggesting that bundling loan payments with familiar utility bills may enhance the likelihood of timely repayments compared to other forms of financing. This method is seen to reduce the risk of loan defaults, suggesting that combining loan obligations with utility bills—a routine expense for most buildings—may encourage more consistent repayment behaviors [15,16,27]. The figure below illustrates the basic payment structure of OBF, detailing how the costs of energy upgrades are financed through utility bills and where the capital for project upgrade comes from.

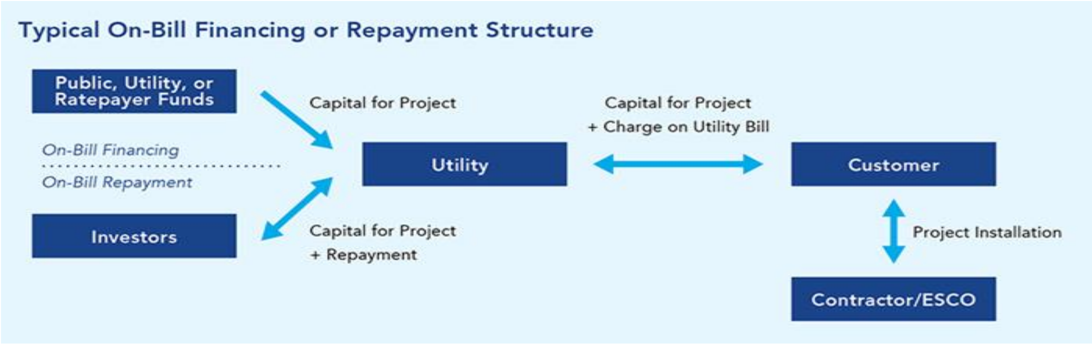


Figure 3: OBF payment structure [28].

Unlike ESPCs, which involve financial arrangements where an ESCO finances and implements energy-saving measures and gets paid from the resulting savings, OBF simplifies the process for the consumer. The main distinction that makes OBF stand out is its direct billing and repayment mechanism through utility bills. This direct billing method not only simplifies the financial process for consumers, making the upgrade more accessible, but also enhances the ease of adoption and reduces administrative overhead from third-party dependency.

Moreover, OBF addresses the split incentive problem, which poses a significant barrier to energy efficiency investment for commercial building sectors. This problem arises when building owners are hesitant to invest in energy-efficient improvements because it is the tenants who typically reap the utility savings benefits. OBF navigates this issue by linking loan repayments directly to the property's utility meter, rather than to the owners or tenant [29]. As a result, the financial responsibility for the energy upgrades is assumed by the current occupants who enjoy the upgrade to ensure that the costs and the benefits are equitably distributed.

These programs are designed to be consumer-friendly, offering financial terms that often include low or no interest and extended repayment periods, thereby making energy upgrades more accessible to a wider demographic [30]. Some OBF programs use the energy savings achieved post-upgrade as a form of security for the loan, which not only incentivizes energy efficiency but also aligns the financing with the actual energy savings [31]. This mechanism ensures that the benefits of energy improvements are directly experienced by the borrower, reinforcing the link between energy conservation and financial savings.

OBF initiatives also extend credit opportunities by evaluating utility payment histories rather than traditional credit scores, thus democratizing access to energy efficiency financing. This aspect is particularly impactful for communities that historically have limited access to credit due to socioeconomic barriers [32,33]. By categorizing the loan as a part of the service bill, OBF programs avoid encumbering consumers with additional reported debt, thus preserving their ability to seek credit for other purposes.

2.2.2. Asset-Backed Securities

Private financing plays a crucial role in supporting projects across a wide range of sectors, offering an alternative to traditional bank loans and public funding sources. Within conventional markets, Asset-Backed Securities (ABS) stand out as a compelling mechanism for raising capital. It converts illiquid assets, such as loans, leases, receivables, into liquid securities. The essence of ABS is to create a financial product that investors can buy and sell, offering a way for the original owners of the assets to gain immediate liquidity and access to new funding sources [34].

Once the assets are pooled together, they are typically transferred to a separate legal entity known as a Special Purpose Vehicle (SPV), established specifically for the securitization process. This SPV issues securities backed by the pooled assets, which are then introduced into the capital market [35]. The issued securities are typically rated by credit rating agencies to provide investors with an indication of their risk level. Higher-rated securities are considered safer but may offer lower returns, while lower-rated securities carry higher risk but the potential for higher returns [36, 37]. By selling these securities in the capital market, the SPV enables a broader spectrum of investors to participate and fund the project. The payments made by borrowers on these assets generate cash flow, which is then passed on to the investors holding the securities.

The concept of leveraging cash flows through Asset-Backed Securities (ABS) has established a strong precedent in the energy sector, especially within the solar industry. This financial mechanism secures the consistent cash flows from residential solar installations, bundling future revenue from energy production or lease payments into securities for investor purchase [38,39]. Solar securitization pools these cash flows, allowing investors to support renewable energy with the prospect of stable returns, while providing solar providers a new avenue for capital at potentially lower costs than traditional finance methods. This approach streamlines the deployment of solar projects by efficiently raising capital through the financial markets. Repayment of this funding is typically done through two main avenues: Power Purchase Agreements (PPAs) and leasing models. In PPAs, building owners agree to purchase the electricity generated by the solar panels at a predetermined price for a specific duration [3]. This arrangement ensures a reliable cash flow from the sale of electricity. Alternatively, in leasing models, solar panels are leased to homeowners or businesses, who then pay a fixed monthly fee for the use of the solar panels [38].

2.2.3. Risk Mitigation

In energy financing, managing risk is crucial for attracting investors. Investments in this sector carry risks from technical failures, market fluctuations, regulatory changes, and energy price volatility, adding uncertainty to returns[40]. Addressing these risks is essential for increasing investment and accessibility.

Diversification is a key strategy in economics and finance, spreading financial assets across different areas to reduce risk and enhance returns [41]. In the energy sector, diversification involves investing in various energy sources and technologies to mitigate risks associated with any single asset. By balancing investments in solar installations, electrified HVAC systems, and the electric vehicle industry, investors can protect against industry-specific regulatory changes, market demand fluctuations, and technological disruptions, ensuring more stable returns [42].

Another effective risk mitigation strategy is using guarantee instruments, borrowed from the World Bank's Guarantee Program. A third party, such as a government or financial institution, provides guarantees to cover potential losses, encouraging investment in riskier projects [43]. For example, the Climate Policy Initiative recommends a first-loss protection instrument for green bonds, where a funding institution or governmental party bears the highest risk, protecting other investors and making clean energy projects more attractive [44]. These guarantees are crucial for the bankability of clean energy projects, particularly those involving advanced HVAC systems. By providing a safeguard against defaults and revenue losses, they encourage investment in emerging technologies and markets, especially when projects are pooled under a single protective mechanism [45, 46].

3. Evaluative Criteria

3.1. Benefit Cost Analysis

This criterion estimates the net present value (NPV) of each policy option over 25 years using a 7% discount rate. The analysis will undertake a benefit cost analysis (BCA) to monetize the advantages and expenses. Market prices will be used to value energy savings, and shadow pricing will be applied where market values are not available for certain benefits and costs. Additionally, a sensitivity analysis will assess how different baseline assumptions (such as the discount rate, electricity price, and the number of participants) might influence the BCA results (See Appendix). The alternatives will be ranked by NPV, assigning a score of 5, 4, or 3.

Benefits: Energy savings (including "rebound effect"), reduced healthcare costs from better air quality, and improved quality of life from efficiency upgrades.

Costs: Operational costs for administrators, HVAC upgrade costs, opportunity costs of city funds, and deadweight loss (DWL) from market distortions.

3.2. Equity

The equity criterion evaluates the potential of policy alternatives to improve the affordability and accessibility of energy efficiency upgrades, particularly in states with lower adoption rates. Drawing from policy literature and case studies, the evaluation will consider how costs and benefits are distributed among stakeholders. Alternatives will be categorized and scored as high (5), medium (3), or low (1) equity based on their impact on disadvantaged groups and states.

3.3. Administrative Feasibility

The assessment of administrative feasibility will evaluate the ability of state governments and relevant stakeholders—such as utility companies, property owners, and residents—to effectively execute policy options. This criterion will categorize alternatives as high (5), medium (3), or low (1) levels of feasibility based on their ease of implementation, resource requirements, and stakeholder support.

3.4. Financial Stability

This criterion assesses the financial risks of different policy alternatives, focusing on potential changes in payment terms and default rates. It evaluates how these risks impact the overall financial viability from both lenders' and borrowers' perspectives. Alternatives will be categorized as high (5), medium (3), or low (1) financial stability based on their inherent risks and the effectiveness of their risk management practices.

4. Policy Alternatives & Evaluation

4.1. Alternative 1: Expanding On-Bill Financing (OBF) Programs

This alternative proposes expanding On-Bill Financing (OBF) programs to include commercial buildings across the United States, leveraging municipal utilities and energy service providers. The program would provide upfront funding for HVAC installations, sourced from federal initiatives, municipal utilities, and energy service providers, ensuring broad access regardless of location [47]. A national framework would manage and distribute these funds, allowing flexibility to address the specific needs and regulations of different states and utility jurisdictions.

OBF operates through partnerships with utility companies, enabling building owners or renters to finance energy-saving upgrades and repay the investment via their monthly utility bills. This approach leverages the utility's established customer relationships and removes the initial cost barrier of HVAC installation, aligning repayment with energy savings [29]. One key benefit of OBF is its accessibility. Some programs consider customers' utility bill payment history instead of traditional credit checks, making it easier for more customers to qualify [48]. Investors also see OBF as a secure funding method due to the reliability of utility bill payments [49].

Commercial property owners would be required to apply for financing for eligible energy-saving projects, determined by factors such as utility bill payment history and projected energy savings. Projects would be guided by energy audits to ensure significant energy savings potential [50]. Approved projects would be carried out by certified contractors, with costs repaid over up to 15 years at zero percent interest through an additional charge on the monthly utility bill [51]. The charge would be calculated to ensure bill neutrality, meaning the energy savings would match or exceed the repayment amount. The program would also adopt a tariffed model, tying repayment obligations to the property meter rather than the individual business owner, ensuring continuity of payments if the property changes hands [33, 50].

Benefit Cost Analysis: This alternative, evaluated at the state level, has a Net Present Value (NPV) of $7,298,891,671.93 and scores 4. The OBF program offers significant energy conservation and comfort benefits for 4,000 commercial buildings, contributing to healthcare savings from reduced air pollution. Costs include resource expenditures for upgrades, opportunity costs of governmental fiscal allocations, and administrative expenses.

Equity: This policy scores 5 for equity. It bypasses traditional credit scoring by using utility payment history for qualification, benefiting businesses with fluctuating credit scores. This approach removes financial barriers and credit checks, ensuring eligibility for those with consistent utility bill payments [52]. The benefits are equitably distributed, enhancing property value for owners and reducing energy expenses for tenants, addressing divergent interests between tenants and landlords [29].

Administrative Feasibility: The feasibility of implementing the OBF program is medium, scoring 3. The GSA has a high level of administrative capacity due to its experience with large-scale projects, but OBF requires close coordination with utility companies and energy service providers. Implementing this nationwide would need collaboration with existing financial and property management systems to accommodate additional billing charges and track energy savings and repayments accurately. Some states' main power companies may be reluctant to push this implementation. However, the GSA's current infrastructure can support such integration, and the GSA is exempt from local and state codes due to federal preemption.

Financial Risk: This alternative scores high with a rating of 5 for managing financial risk. OBF has a low default risk since repayments are integrated into utility bills—a priority payment for most consumers, given the essential nature of utility services. Seventy-two percent of consumers prioritize utility bills, resulting in significantly lower default rates compared to other types of unsecured debt [27,49]. The structure of OBF avoids significant changes in payment terms, ensuring financial stability for payers. Repayment terms are clearly defined, with mechanisms to prevent substantial increases in monthly utility bills [50, 53].

4.2. Alternative 2: Guarantee Facility Model

This alternative involves leveraging a Guarantee Facility Model to mitigate financial risks for lenders and investors. It includes two main components: project pooling and first-loss protection.

The GSA should identify and prioritize prospective energy efficiency projects, such as electrified HVAC system installations, that have significant impact potential. These projects would be aggregated into a single portfolio to dilute the risk associated with any single project [54]. Once a project is deemed viable, the GSA will partner with financial institutions to provide the necessary capital for upfront installation costs. The GSA will offer a guarantee covering the first-loss exposure, encouraging banks and private investors to fund these projects with reduced risk of potential losses [43, 44]. If a project fails to meet financial returns, the guarantor covers a portion of the losses, making lenders more willing to finance these initiatives. This guarantee results in more favorable loan terms, such as lower interest rates and extended repayment periods, improving cash flow and financial viability for building owners [55, 56].

Benefit Cost Analysis: This alternative has an NPV of $8,153,256,622.66 and scores 5. Benefits include energy conservation, enhanced living conditions for 4,000 households, and healthcare savings. Costs encompass upgrade expenses, deadweight loss from government spending, and operational costs for both the government and private lenders, including employee salaries, office space, marketing, and transaction costs.

Equity: This policy alternative scores medium with a rating of 3. While guarantee instruments reduce investment risks and could theoretically support projects in underserved communities, the complexity and scale might favor larger projects. Without intentional design prioritizing equity, investments may naturally flow to less challenging, more financially secure projects, potentially bypassing those in high-impact regions [57, 58].

Administrative Feasibility: This alternative scores medium to high with a rating of 4. The GSA has strong administrative capabilities and experience managing sustainability and energy efficiency initiatives. The integration of guarantee instruments into existing programs would require minimal additional overhead. Government backing enhances the GSA's ability to manage guarantees, reducing perceived risks and streamlining risk assessment and management.

Financial Risk: This alternative scores high with a rating of 5. The whole purpose of this model is to prioritize stability and minimize the likelihood of significant changes in payment terms [59].The first-loss protection acts as a financial buffer, reducing lenders' and investors' exposure to risk. Project pooling spreads financial risk across multiple projects, ensuring that the failure of a single project has less impact on the overall investment.

4.3. Alternative 3: Asset-Backed Securities

This alternative proposes enhancing the adoption rate of electrified HVAC systems in the U.S. through the use of Asset-Backed Securities (ABS). The process begins with property owners securing loans or leases for HVAC upgrades. These financial agreements are then pooled into a larger portfolio, simplifying the investment structure and preparing the assets for securitization [36, 60]. These pooled assets are then transformed into securities, categorized by risk and potential profit to match investors' profiles. Investors in the capital markets provide the necessary upfront funding for these projects. The return on investment is tied to the repayment of the underlying loans or leases, which are repaid as property owners realize energy savings from their upgraded HVAC systems [61]. Payments are first directed to the highest-rated groups, ensuring lower-risk investors are paid quickly, while higher-risk investors stand to gain more if the projects succeed [60].

The success of this proposal depends on the repayment of loans or leases. If repayments falter due to underperformance or financial difficulties, cash flow to investors is reduced, increasing the perceived risk and demand for higher future returns, complicating future borrowing [62, 63]. To mitigate this, the GSA can tie ABS repayments directly to the performance of energy efficiency upgrades, making investor returns more predictable and linked to actual energy savings.

Benefit Cost Analysis: This alternative has an NPV of $7,248,992,804.37 and scores 3. Benefits include energy savings, enhanced comfort, and healthcare savings. Costs include resource expenditures for upgrades, opportunity costs of government allocations, and administrative expenses such as marketing, workforce compensation, transaction costs, legal fees, and compliance costs.

Equity: This alternative scores low to medium with a rating of 2. While ABS can distribute risk among investors and make funding more accessible for smaller or riskier projects, the complexity and potential lack of transparency may favor larger, sophisticated investors and property owners, disadvantaging smaller players [64]. However, if well-structured, ABS can lower project costs compared to traditional loans, making HVAC upgrades feasible for a wider range of commercial buildings.

Administrative Feasibility: This alternative scores high with a rating of 5. Growing interest in sustainable investments enhances the feasibility of implementing ABS for HVAC upgrades. The success of green bonds offers valuable lessons, as the market's acceptance of securities tied to environmental benefits suggests receptiveness to ABS. The GSA has the capacity and experience to manage such a mechanism, supported by potential legislation encouraging private investment in public infrastructure. Standardizing asset quality for ABS under ASHRAE Standard 90.1 should not be an issue, as this standard is widely recognized for energy efficiency in buildings.

Financial Risk: This alternative scores moderately well with a rating of 3. While pooling loans or leases into ABS offers risk diversification, overall stability relies on consistent repayment. Linking repayments to the performance of energy efficiency upgrades can reduce uncertainty around cash flows, but accurate measurement and verification of energy savings are crucial to this strategy's success [65].

4.4. Outcome Matrix & Sensitivity Analysis

Table 1. Outcome matrix & sensitivity analysis

Alternative	Benefit Cost Analysis	Equity	Administrative Feasibility	Financial Risk	Overall Score
On-Bill Financing	Medium-High (4): NPV: $ 7,298,891,671.9	High (5) : Reduces limitations on credit access, improves cost-effectiveness, and equitable benefit (split incentives)	Medium (3): Low administrative feasibility for some states due to difference in regional building codes.	High (5): Defined terms prevent major payment shifts; low default risk for utility bills.	Score: 17
Guarantee Facility Model	High (5): NPV: $ 8,153,256,622.7	Medium (3): Selective accessibility; Unbalanced allocation	Medium-High (4): Strong administrative strength; Capability of high-risk management	High (5): Financial buffer; Diversified portfolio	Score: 17
Asset-Backed Securities	Medium (3): NPV: $ 7,248,992,804.4	Low-Medium (2): Risk distribution; Investor bias concern	High (5): GSA's experience with capital financing; Favorable marketing conditions	Medium (3): Potential for variable investor returns	Score: 13

When the discount rate increases from 5% to 7%, the NPV for all three alternatives decreases significantly. The OBF model is more sensitive to discount rate changes, suggesting its cash flows are expected further in the future. From 5-7% to 7-10%, the impact on NPV lessens, indicating that initial cash flows are more affected by lower rates. For the GSA, this means higher discount rates lead to a more stable risk profile.

All three alternatives show near-perfect elasticity with participant count changes, meaning NPVs adjust almost proportionately to the number of participants. This implies a stable financial outlook, as NPVs rise or fall in direct proportion to participant numbers. Factors like energy savings percentage, electricity rate increases, marketing costs, non-energy savings, and the rebound effect exhibit inelastic responses. Changes in these variables have minimal impact on participant numbers, suggesting predictable participant behavior and stable program planning without significant adjustments for these factors.

The NPV for each alternative reaches zero if healthcare savings per household and kWh savings fall significantly below typical estimates or if annual new household participation drops drastically. For example, the NPV for the Guarantee Facility Model would become zero if fewer than 1080 households participate annually, a scenario considered highly unlikely given the scale of this proposed program.

5. Recommendations

This analysis recommends implementing Alternative 1: On-Bill Financing (OBF) as the optimal strategy for the U.S. commercial building sector under GSA's authority.

The Benefit-Cost Analysis shows that the Guarantee Facility Model has the highest NPV, while OBF and ABS have similar but lower NPVs. However, OBF is favored due to its emphasis on equity and widespread adoption. OBF enables property owners and tenants to finance energy-saving upgrades through utility bills, removing the need for substantial upfront investments. This approach lowers the barrier to entry for smaller businesses and underserved communities.

OBF also addresses market penetration and adoption hurdles more effectively than the Guarantee Facility Model. While the Guarantee Facility Model offers favorable financial returns, it may not directly tackle the adoption barriers and split incentive problems. OBF ties financing repayment to utility bills, linking investment with energy savings and encouraging broader uptake. Prioritizing OBF over ABS focuses on immediate adoption barriers rather than accessing broader capital. ABS, although effective in mobilizing large-scale financing, does not address upfront cost barriers and misaligned incentives as directly as OBF. OBF provides a straightforward approach, linking investment directly to utility bill savings and ensuring immediate benefits, promoting broader and more equitable adoption of energy-efficient systems.

However, using ABS as a complementary mechanism can expand financing options. ABS can aggregate and refinance existing energy efficiency loans, freeing up more capital for new OBF projects. This dual approach harnesses the strengths of both models: OBF's effectiveness in addressing upfront cost barriers and ABS's capacity to mobilize large-scale investment.

OBF programs have been successfully applied in residential buildings across several states, providing valuable experience and insights that can be adapted for commercial applications. This existing knowledge makes nationwide implementation more feasible. While OBF mitigates initial financial barriers, it alone does not stimulate demand for upgrades. Therefore, it is recommended that GSA support the program with information campaigns to increase consumer awareness and offer technical guidance for the commercial building sector.

6. Implementation

To initiate the OBF program, the GSA's Office of Federal High-Performance Green Buildings (OFHPGB) should first create a detailed proposal and seek approval from GSA's executive leadership. The proposal should include a clear timeline for implementation and structural recommendations. OFHPGB should form a cross-departmental team, incorporating expertise from the Office of Government-wide Policy and the Federal Buildings Fund, to ensure the program's sustainability, compliance, and financial viability. This team will be responsible for refining the proposal, identifying areas for improvement, and making necessary adjustments for nationwide implementation.

Following this, the GSA should explore partnerships with major federal utility service providers, including the Tennessee Valley Authority (TVA) and regional utilities that serve many federal facilities. These partnerships are crucial for integrating OBF mechanisms into existing billing systems, allowing for the recovery of investments in energy efficiency directly through utility bills. Negotiations should focus on creating agreements that make the inclusion of energy improvement costs in billing both feasible and efficient, ensuring customers can repay these investments over time seamlessly. Initial funding allocated for upgrades in 2026, based on projections for 4,000 state-level participants, is estimated at $418.2 million. To supplement the funding available from the Federal Buildings Fund and other budget allocations, the GSA must seek partnerships with financial institutions experienced in energy financing and committed to sustainability. Banks and entities like the Green Investment Group, Bank of America's Environmental Business Initiative, or the World Bank can offer loans or lines of credit tailored for HVAC installation. The GSA should focus on establishing terms that favor long-term sustainability and financial viability.

Alternatively, the GSA could propose the program directly to Congress and lobby for legislation mandating federal utility providers to implement an OBF program. However, the program stands a better chance of success if federal utility providers agree to administer it through internal procedures and negotiations, as a utility's commitment to OBF significantly influences its success [33]. For program design and planning, it is recommended to tailor the OBF program specifically to the unique needs of federal facilities. The GSA will need to develop inclusive eligibility criteria, favorable financing terms, and identify impactful energy efficiency measures (EEMs). Pilot projects in selected federal buildings will serve as crucial testing grounds, while the GSA continues to collaborate with facility managers, sustainability officers, financial institutions, and ESCOs.

If federal utility providers do not accept the proposal, the GSA might consider creating an internal fund dedicated to energy efficiency projects, similar to a green revolving fund, where savings from energy efficiency projects are reinvested into new projects. This self-sustaining fund could support ongoing energy efficiency improvements without relying on external utility providers. Alternatively, the GSA could recommend the Guarantee Facility Model to allow ESCOs or the government to absorb a significant portion of the project risk so that utility providers will be more likely to cooperate.

Upon initiating the OBF program, the GSA's role will encompass program marketing and evaluation. The OBF program often faces challenges generating demand, resulting in lower-than-anticipated market penetration [29]. To address this and enhance the program's reach, the GSA should form strategic partnerships with federal utility providers to initiate a comprehensive informational campaign. This campaign should focus on promoting energy efficiency benefits to facilities most likely to see significant improvements, including those in underserved communities. The GSA can lead by example, demonstrating the efficacy of the OBF program by successfully implementing it within its managed facilities, providing tangible evidence of the program's effectiveness in reducing energy consumption and costs, and building confidence among potential participants.

To increase consumer awareness, the GSA should leverage psychological principles influencing decision-making and behavior. By showcasing real-life testimonials and case studies from early adopters who have benefited from the program, the GSA can use social proof to illustrate the tangible impacts of energy efficiency improvements, indirectly encouraging others to participate. For instance, the program is projected to deliver total benefits of approximately $103 million in the first year alone—comprising $40 million from energy savings, $6 million from improved comfort, and $57 million from enhanced health and safety measures. As these figures are projected to increase annually, the growing benefits provide strong incentives for others to join the program, enhancing the credibility of the testimonials. When individuals see that peers or similar entities have successfully implemented energy efficiency measures and are enjoying the benefits, they are more likely to feel that participating is a good decision [66].

Furthermore, the GSA should emphasize stories demonstrating how specific energy-saving measures have resulted in significant savings and improved comfort within federal buildings, as these narratives can strongly appeal to potential participants. Leading this informational campaign, the GSA should also prioritize collecting and analyzing data on the OBF program to assess its cost-effectiveness over time.

7. Conclusion

Electrifying HVAC systems in commercial buildings is crucial for reducing energy use and greenhouse gas emissions, aligning with national goals. However, financial barriers hinder this transformation, highlighting the need for effective financing solutions. Among the three alternatives analyzed—On-Bill Financing (OBF), Asset-Backed Securities (ABS), and the Guarantee Facility Model—OBF stands out for addressing equity issues and upfront cost barriers. This recommendation does not overshadow the contributions of ABS in expanding financing or the robust returns and risk mitigation offered by the Guarantee Facility Model.

The study reveals three main limitations: the voluntary nature of participation, the scarcity of comprehensive data on energy savings, and variability in state and regional building codes. Voluntary participation makes it difficult to establish causal relationships between program availability and the adoption of energy-efficient HVAC systems. The lack of comprehensive data and the "rebound effect" complicate the evaluation of actual energy savings. Additionally, differing building codes across states affect the replicability of financing strategies.

As the commercial sector evolves, so will financing dynamics for energy efficiency. Future research should focus on the scalability of successful models, integrating emerging technologies, and adapting financing strategies to new regulatory landscapes. Continued innovation, data-driven analysis, and policy alignment are essential for fostering a commercial sector that thrives economically while contributing to environmental sustainability.

References

[1] Energy Information Administration (EIA), "2018 Commercial Buildings Energy Consumption Survey," Office of Energy Statistics, Department of Energy (DOE), Nov. 2023.

[2] Office of Energy Efficiency & Renewable Energy (EERE), "About the Commercial Buildings Integration Program," Department of Energy (DOE), Apr. 22, 2020.

[3] Environmental Protection Agency, "Solar power purchase agreements," Jan. 2024.

[4] United Nations Environment Programme (UNEP), "Emissions Gap Report 2023," 2023.

[5] Intergovernmental Panel on Climate Change, "Press release: Climate change 2022: Mitigation of climate change," Apr. 4, 2022.

[6] B. Kosik, "Four strategies for decarbonization and electrification in commercial buildings," Consulting-Specifying Engineer, May 10, 2023.

[7] Environmental Protection Agency, "Heating, Ventilation and Air-Conditioning Systems, Part of Indoor Air Quality Design Tools for Schools," 2023.

[8] S. Nadel and C. Perry, "Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges," American Council for an Energy-Efficient Economy, 2020.

[9] Department of Energy, "Heat Pump Water Heaters," 2022. [Online]. Available: https://www.energy.gov/energysaver/heat-pump-water-heaters.

[10] Super-Efficient Dryer Initiative (SEDI), "Potential Energy Savings from Heat Pump Dryers in North America," 2021.

[11] Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," United States Environmental Protection Agency, 2022. [Online]. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[12] S. Hill, N. Dirr, and T. Harrison, "Equitable Electrification: Program Models That Work for Existing Low Income Multifamily Buildings," in Proceedings of the 2020 ACEEE Summer Study on Energy Efficiency in Buildings, vol. 13, pp. 107-124, 2020.

[13] S. Bird and D. Hernández, "Policy options for the split incentive: Increasing energy efficiency for low-income renters," Energy Policy, vol. 48, pp. 506-514, Sep. 2012.

[14] OECD, "Financial markets and climate transition: Opportunities, challenges and policy implications", 2021

[15] K. Gillingham and K. Palmer, "Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence," Review of Environmental Economics and Policy, vol. 8, no. 1, 2014.

[16] K. Palmer, M. Walls, and T. Gerarden, "Borrowing to Save Energy: An Assessment of Energy-Efficiency Financing Programs," Resources for the Future, 2012.

[17] T. Gerarden, R. G. Newell, and R. N. Stavins, "Assessing the Energy-Efficiency Gap," NBER Working Paper No. w20904, 2015.

[18] Environmental Protection Agency, "Commercial Property Assessed Clean Energy," 2023. [Online]. Available: https://www.epa.gov/statelocalenergy/commercial-property-assessed-clean-energy.

[19] J. Deason, G. Leventis, C. A. Goldman, and J. P. Carvallo, "Energy Efficiency Program Financing," Berkeley Lab Electricity Markets & Policy Group, 2016.

[20] PACE Financing, "ABFH Uses PACE Financing for New Hotel Development," City of Milwaukee, n.d.

[21] Department of Energy, "Energy Savings Performance Contracts for Federal Agencies," Federal Energy Management Program, 2022.

[22] A. Kirkpatrick and L. Bennear, "Promoting clean energy investment: An empirical analysis of property assessed clean energy," Journal of Environmental Economics and Management, vol. 68, no. 2, pp. 357-375, 2014.

[23] Oregon Department of Energy, "Energy savings performance contracting: A guide for Oregon state agencies," Feb. 2016.

[24] Department of Energy, "ESPC Financing," Better Buildings Solution Center, 2021

[25] F. Liu, I. Voitekhovitch, D. Hankinson, C. Parcels, J. Morrison, and D. Ong, "Belarus - Scaling up energy efficiency retrofit of residential and public buildings: Assessment of investment needs, implementation constraints, financing options, and delivery models," World Bank, 2015.

[26] Performance Services, "The Financial Benefits of Energy Savings Performance Contracts," Oct. 7, 2019.

[27] PYMNTS, "How consumers decide which bills to pay or skip," PYMNTS.com, Jan. 26, 2023.

[28] Department of Energy, "On-Bill Financing/Repayment," Better Buildings Solution Center, 2024.

[29] C. J. Bell, S. Nadel, and S. Hayes, "On-Bill Financing for Energy Efficiency Improvements: A Review of Current Program Challenges, Opportunities, and Best Practices," American Council for an Energy-Efficient Economy (ACEEE), 2011.

[30] T. Block, I. Fischer, S. Morgan, and J. Weiss, "The Opportunity for Energy Efficiency Financing Programs in the Southeast," Southeast Energy Efficiency Alliance, 2014.

[31] K. Johnson, et al., "Lessons learned from the field: key strategies for implementing successful on-the-bill financing programs," Energy Efficiency, vol. 5, no. 1, pp. 109-119, 2011.

[32] G. Andersen, J. Durkey, and C. Brown, "Harnessing the Market to Create Energy Savings," National Conference of State Legislatures, 2015.

[33] L. Mundaca and S. Kloke, "On-Bill Financing Programs to Support Low-Carbon Energy Technologies: An Agent-Oriented Assessment," Review of Policy Research, vol. 35, no. 4, 2018

[34] F. J. Fabozzi and V. Kothari, Introduction to Securitization, Wiley, 2008.

[35] G. Gorton and N. S. Souleles, "Special purpose vehicles and securitization," NBER Working Paper No. 11190, 2005.

[36] Guggenheim Investments, "The ABCs of Asset-Backed Securities (ABS): Finding value in complexity: The structure, risks, and investor-friendly features of asset-backed securities," Apr. 3, 2023.

[37] Kroll Bond Rating Agency (KBRA), "Evaluating credit risks in solar securitizations," Oct. 12, 2012.

[38] F. M. O'Sullivan and C. H. Warren, "Solar securitization: An innovation in renewable energy finance," MIT Energy Initiative, 2016.

[39] W. Yin, Z. Zhu, B. Kirkulak-Uludag, and Y. Zhu, "The determinants of green credit and its impact on the performance of Chinese banks," Journal of Cleaner Production, vol. 286, p. 124991, 2021.

[40] Ch. Kaminker and F. Stewart, "The Role of Institutional Investors in Financing Clean Energy," OECD Working Papers on Finance, Insurance and Private Pensions, no. 23, OECD Publishing, 2012.

[41] J. L. Evans, "An Examination of the Principle of Diversification," Journal of Business Finance & Accounting, vol. 2, no. 2, pp. 243-255, 2006.

[42] L. Gitelman, M. Kozhevnikov, and Y. Visotskaya, "Diversification as a method of ensuring the sustainability of energy supply within the energy transition," Resources, vol. 12, no. 19, 2023.

[43] World Bank, "Guarantees Program," n.d. [Online]. Available: https://www.worldbank.org/en/programs/guarantees-program#1.

[44] B. Lorentz, J. Trüby, P. Philip, B. Shirizadeh, and C. Cartry, "Financing the Green Energy Transition: A US$50 trillion catch," Deloitte, Nov. 2023.

[45] T. D'Olier-Lees, G. Cantabrana Fernandez, A. Prabhu, L. Li, P. Georges, E. Gunter, ... C. DeLucia, "Renewable Energy Funding in 2023: A 'Capital Transition' Unleashed," S&P Global, Sep. 14, 2023.

[46] M. Hervé-Mignucci, G. Frisari, V. Micale, and F. Mazza, "Risk gaps & first loss protection mechanisms," Climate Policy Initiative, 2013.

[47] J. Durkay, "On-Bill Financing: Cost-free Energy Efficiency Improvements," National Conference of State Legislatures, 2016.

[48] Collaborative Efficiency & Michigan Saves, "Overcoming the barriers to energy-related investments with an on-bill financing program: A primer for municipal utilities and electric cooperatives," Environmental and Energy Study Institute; C. S. Mott Foundation; Council of Michigan Foundations; Joyce Foundation, 2015.

[49] S. Burr and V. Carlson, "Utility payments as alternative credit data: A reality check," The Brookings Institution Metropolitan Policy Program, Mar. 2007.

[50] P. Henderson, "On-Bill Financing," Natural Resources Defense Council, 2012.

[51] M. Yanez-Barnuevo, "On-Bill Financing: Expanding Access to Energy Efficiency, Clean Energy Adoption, and Electrification for Everyone," Environmental and Energy Study Institute (EESI), ACEEE Summer Study Paper, 2020.

[52] R. Beer, F. Ionescu, and G. Li, "Are Income and Credit Scores Highly Correlated?" FEDS Notes, Board of Governors of the Federal Reserve System, 2018.

[53] Environmental Protection Agency (EPA), "Clean energy finance: On-bill programs," Sep. 2019.

[54] J. Taminiau, J. Byrne, D. Sanchez Carretero, S. Shin, and J. Xu, "Risk mitigation in energy efficiency retrofit projects using automated performance control," IntechOpen, 2021.

[55] Department of Energy, "Loan guarantees for clean energy projects," Federal Register, May 30, 2023.

[56] K. Delaney, "How interest rate buy-downs can be used to complement private capital financing for energy efficiency projects," California Alternative Energy and Advanced Transportation Financing Authority, Mar. 2023.

[57] D. Duma and M. Muñoz Cabré, "Risk mitigation for private utility-scale renewable energy investments," in Risk mitigation and transfer for renewable energy investments: A conceptual review, Chapter 9, Stockholm Environment Institute, 2023.

[58] O. E. Omoju, "Promoting private financing for sustainable energy in Africa: The role of the Africa Energy Guarantee Facility," South African Institute of International Affairs, 2020.

[59] L. Cronk and A. Aktipis, "Design principles for risk-pooling systems," Nature Human Behaviour, vol. 5, pp. 825-833, 2021.

[60] A. Ashcraft, A. Malz, and Z. Pozsar, "The Federal Reserve's Term Asset-Backed Securities Loan Facility," FRBNY Economic Policy Review, Nov. 2012.

[61] N. Cuthbert, A guide to project finance, Dentons, 2013.

[62] R. Kumar, "Chapter 4 - Money Markets, Bond Markets, and Mortgage Markets," in Strategies of Banks and Other Financial Institutions, Academic Press, 2014, pp. 95-123.

[63] Y. Zhao, Y. Yue, and P. Wei, "Financing Advantage of Green Corporate Asset-Backed Securities and its Impact Factors: Evidence in China," Frontiers in Energy Research, 2021.

[64] M. Lemmon, L. X. Liu, M. Q. Mao, and G. Nini, "Securitization and Capital Structure in Nonfinancial Firms: An Empirical Investigation," Journal of Finance, forthcoming, 2013.

[65] D. M. Grueneich, "The next level of energy efficiency: The five challenges ahead," The Electricity Journal, vol. 28, no. 7, pp. 44-56, 2015.

[66] T. A. G. Venema, F. M. Kroese, J. S. Benjamins, and D. T. D. de Ridder, "When in Doubt, Follow the Crowd? Responsiveness to Social Proof Nudges in the Absence of Clear Preferences," Frontiers in Psychology, vol. 11, p. 1385, 2020.

[67] Sanalife, "How to estimate commercial HVAC upgrade costs," Nov. 1, 2021.

[68] K. Cleary and K. Palmer, "Energy efficiency 101," Explainer, Jun. 17, 2020.

[69] CommercialEdge, "Commercial real estate data and listings in one place," n.d. [Online]. Available: https://commercialedge.commercialdemo.cafe/.

[70] J. Voss, "Revisiting Office Space Standards," Haworth, n.d. [Online]. Available: https://www.atworkofficeinteriors.ca/files/resources/Revisiting-office-space-standards-white-paper.pdf.

[71] H. Campbell and R. Brown, "Benefit-Cost Analysis: Financial and Economic Appraisal using Spreadsheets," School of Economics at the University of Queensland, 2016

[72] L. Conway, "December 2023 Fed meeting: Rates stay put," J.P. Morgan Wealth Management, Dec. 14, 2023.

[73] National Institute of Building Sciences, "Financing small commercial building energy performance upgrades: Challenges and opportunities," 2014.

[74] YCharts, "US Average Retail Price of Electricity (I)," n.d.

[75] C. Russell, B. Baatz, R. Cluett, and J. Amann, "Recognizing the value of energy efficiency's multiple benefits," ACEEE, Dec. 2015.

[76] R. Srivastava, "Here's how to scale energy-saving commercial building retrofits," ACEEE, May 4, 2022.

[77] B. Tonn, E. Rose, B. Hawkins, and B. Conlon, "Health and household-related benefits attributable to the Weatherization Assistance Program," Oak Ridge Institute for Science and Education, Sep. 2014.

[78] Office of Energy Efficiency & Renewable Energy (EERE), "ABC blog series: New technology to retrofit America," Department of Energy (DOE), Jan. 28, 2020.

[79] B. Zientara, "How much electricity prices increase per year in the U.S.," Solar Reviews, Mar. 23, 2023.

[80] IotaComm, "Benchmarking commercial building energy use per square foot," Aug. 20, 2020.

[81] P. J. Burke and A. Abayasekara, "The price elasticity of electricity demand in the United States: A three-dimensional analysis," CAMA Working Paper No. 50/2017, SSRN, Aug. 2017.

[82] Salary.com, n.d. [Online]. Available: https://www.salary.com/research/salary/recruiting/

[83] The Energy Efficiency Institute, Inc., "Decision tool for utility managers," 2016.

[84] U.S. Bureau of Labor Statistics, "Financial managers," in Occupational Outlook Handbook, United States Department of Labor, 2022.

[85] S. Delouya, "The US minimum wage has been $7.25 since 2009. What that means for the economy," CNN, Nov. 11, 2023.

[86] Division of Investment Management, "U.S. Securities and Exchange Commission," n.d.

[87] H. Goldwasser and S. Vivekananda, "Term Asset-Backed Securities Loan Facility: Orrick's Guide to 'TALF 2.0'," Sep. 1, 2020.

Appendix: BCA Assumption Breakdown

The tables below present the analysis assumptions used for the BCA calculations and the breakdown of costs for each alternative. This analysis evaluates the effectiveness and costs of each alternative using a 7 percent discount rate and a 25-year time horizon from 2024 to 2049. This BCA includes many assumptions, most of which are derived from relevant research and are cited accordingly. Other assumptions are generated by the author. While the sensitivity analysis addresses certain unpredictability within the assessment, this BCA primarily serves as an instrument for contrasting the different options available.

The following table illustrates general assumption for selected years in the 25-year time horizon from 2024-2049.

Parameter	Value	Source
All costs occur at year end (standard practice)	year end	Standard practice
All $ are in 2024$	Money value of 2024$	Author decision
Discount rate	7%	Author decision
Number of new commercial buildings participating in program each year	4000	Author assumption
Program lifetime (of upgrade offerings) in years	10	Typical standard
Average loan amount/cost of efficiency upgrade per building	$ 104,550	[67]
Average rebound effect per household	0.2	[68]
maximum loan term in years	15	
Average rent per square foot of office space per year	37.35	[69]
Standard cubicle size in square feet	64	[70]
Deadweight loss factor for government spending	1.25	[71]
Forecasting interest rate	5%	[72]
The median of commercial building size(sq ft)	5100	[73]
$/kWh price of electricity in 2024	$ 0.1255	[74]
Average value of comfort as a percentage of utility bill savings	15%	[75]
Average annual energy savings as a percent of total energy use	40%	[76]
Annual value of non-energy savings per building (health, safety)	$ 14,148.00	[77]
Targeted number of commercial building (90% retrofitting goal)	24,444,000	[78]

Baseline Assumption

The following table illustrates baseline energy savings assumption for selected years in the 25-year time horizon from 2024-2049.

Parameter	Value	Source
Annual increase in $/kWh (electricity price)	2.36%	[79]
Average annual electricity consumption in kWh per sq ft for commercial building	15	[80]
Average monthly electricity consumption in kWh per sqft for commercial building	1.25	Author's calculation
Average Size of Commercial Building in sqft	16,400	[1]
Average monthly electricity consumption in kWh per building	20,500	[1]
Price elasticity of electricity demand	-0.4	[81]
Response of electricity consumption	-0.012928	Author's Calculation

Additional Assumption

The following table illustrates additional assumptions for each alternative

On-Bill Financing	Value	Source
Estimated salary for finance officer	$ 101,971.00	[82]
Number of additional employees for program operation	10	[83]
Cost of marketing per participant	$ 241.00	[33]
Additional hours spent on repayment each year	0	Author assumption
Guarantee Facility Model		
Loss compensation rate	90%	
Default rate	4.50%	Author assumption
Estimated salary for U.S. government finance officer	$ 124,400.00	[84]
Estimated salary for financial institution employee (lenders)	$ 80,566	[82]
Number of additional government employees for program operation	40	Author's decision [83]
Additional hours spent on repayment each year per building	1	Author's assumption

Minimum wage (U.S.)	$ 7.25	[85]
Number of additional financial institution employee (lenders)	40	Author's decision
Asset-Backed Securities		
Estimated salary for finance officer	$101,971.00	[82]
Number of additional employees for program operation	10	[83]
Additional hours spent on repayment each year	1	Author assumption
Minimum Wage(the U.S. average)	$ 7.25	[85]
Annual Salary of Security Attorney	$ 90,787.00	[82]
Number of Security Attorney for program operation	16	Author assumption: 1 attorney per 250 participants (ceiling to the next integer)
Minimal fees for registering the securities per participants	$ 150.00	[86]
Annual Salary of Fulltime Compliance Officer	$ 86,304.00	[82]
Number of Security Fulltime Compliance Officer for program operation	27	Author assumption: 1 officer per 150 participants per year. [87]

Additional Information

The underlying assumptions for valuing improvements in comfort and healthcare savings are extracted from the breadth of existing literature. Energy efficiency enhancements not only lead to direct energy savings but also elevate the comfort and health levels within households. The inclusion of such co-benefits in the analysis is pivotal because they serve as significant motivators for households contemplating investments in energy efficiency improvements, thereby considerably enhancing the net present value of benefits.

Transaction costs borne by building owners who participate in policy alternatives are estimated by employing the national minimum wage as a proxy for the opportunity cost of the program participants' time. This approach assumes that the time spent by building owners on program-related activities could otherwise be used for labor compensated at the minimum wage rate. Also, transaction costs for owners of commercial buildings are anticipated to be higher than the national minimum wage, which has been used as a benchmark in the analysis due to the lack of a more precise alternative wage rate for valuation.

Additionally, the estimation of healthcare savings per household leverages findings from a study examining the Department of Energy's Weatherization Assistance Program (WAP). This study provides crucial insights into the economic value of non-energy benefits, specifically in the realms of health and safety improvements, on a per-building basis. The average annual value of these non-energy benefits for a commercial building is assessed to be $14,148. This number may vary significantly based on the specific uses and occupancies of the buildings.