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Making Buildings Part of the Climate Solution with Flexible Innovative Financing

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ABSTRACT

Lack of attractive financing remains one of the most significant barriers to energy-efficiency improvements in commercial buildings. This paper examines a flexible financing policy that would support state and local initiatives via loan loss reserves, tax lien financing, revolving loans, performance contracts, and on-bill programs. We examine the impact of different levels of subsidy covering different numbers of technologies, ultimately selecting a 10% subsidy for 64 qualifying technologies. This policy would save almost half a quad of energy in 2020 and 1.04 quads in 2035, producing net social benefits of $105 billion and a benefit/cost ratio of 1.9. Technologies with significant growth in market share include advanced fluorescents and variable-air-volume ventilation systems. Case studies of other technologies illustrate the advantage of optimizing financial assistance to reflect product maturity and cost-competiveness. A 10% subsidy would produce an estimated ten-fold increase in the amount spent on high-efficiency equipment in 2035, and the $3.9 billion subsidy in that year would have only an 11% rate of free ridership.

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Any errors in this report are the responsibility of the authors alone.

1. Introduction

The lack of attractive financing options remains one of the most significant barriers to achieving deep energy-efficiency upgrades in private commercial buildings (Prindle, 2010; Johnson Controls/IFMA, 2010; Kammen, 2009). The American Recovery and Reinvestment Act (ARRA) provided state and local governments with a one-time infusion of resources to facilitate investments. Many jurisdictions expanded or created revolving loan funds or other mechanisms to maintain programs beyond the ARRA expiration in 2012. Nevertheless, the return of the State Energy Program (SEP) and Energy Efficiency and Conservation Block Grants (EECBG) to the appropriations levels that existed before the Recovery Act will result in fewer opportunities to expand commercial energy efficiency. The Department of Energy (DOE) could, however, support state and local governments in the development of innovative financing programs that build partnerships between government, financial institutions, and the commercial sector. This paper analyzes the experience of state and local financing programs, provides information on opportunities for federal involvement, and models the potential impact of expanded financing opportunities using the National Energy Modeling System maintained by the Georgia Institute of Technology (GT-NEMS).

A flexible innovative financing policy targeting commercial buildings could support efforts across the country by providing limited federal resources through state and local governments and partnerships with the financial, utility, and other business communities. Public-private partnerships have already helped to yield low-cost savings in the public building stock through energy savings performance contracts (Energy Services Coalition, 2011) and can facilitate additional opportunities for the private sector. Programs can improve the competitiveness of energy efficiency projects in capital planning and reduce interest rates for consumers (Sherlock and Maguire, 2011). These programs offer an opportunity for employment and can provide assistance to small businesses. With state and local governments across the country aiming to meet aggressive climate and energy goals, federal support and private sector partners can help overcome financial challenges. While the residential sector will see new opportunities in state and locally leveraged financing through the Warehouse for Energy Efficiency Loans (WHEEL) (Shreve, 2012), this program could drive demand and fill the gap in the commercial marketplace.

This analysis will also compare the “carrot” of a financing policy to the “stick” of carbon taxes in terms of impacts on the commercial buildings sector using the assumptions and results of Brown, Cox, and Sun (2012a, b). In theory, the carbon tax is a more economically efficient mechanism to achieve greenhouse gas emissions reductions and to generate the potential economic benefits of clean energy deployment. Reducing the first costs of energy efficiency upgrades through financing, however, is a useful policy tool that could supplement the benefits of a carbon tax or could be a “second best” policy in the absence of a carbon tax. Although McKibben, Morris, and Wilcoxen (2010) find in their model that the carbon tax has the impact of increasing welfare while subsidies decrease welfare (but boost the economy), financing and the carbon tax can also work together as a consistent “policy package” (Harmelink, Nilsson, and Harmsen, 2008) to further drive the transition to a low-carbon economy and enhance the potential economic co-benefits of energy efficiency. Fischer and Newell (2004) suggest that subsidies have the disadvantage of not providing incentives to reduce inefficient and polluting technologies, but in fact, by subsidizing their clean and efficient alternatives, the inferior durable goods will have difficulty competing.

2. The Concept of Flexible Innovative Financing

In the flexible financing option examined here, it is envisioned that DOE would offer matching pass-through funds to states to support a portfolio of innovative financing programs that encourage energy-efficiency investments in commercial buildings. In the US, non-tax rebates for energy-efficient measures are more common than tax incentives. Most states offer rebates to incentivize the purchase of individual energy-efficient appliances and equipment. On the other hand, California offers a rebate for measures that save at least 15% of a home's energy use, with larger rebates given for larger savings (Neuhoff et al., 2012). An innovative financing policy could enable either approach.

The suite of financing mechanisms to be supported could include approaches such as loan loss reserves, property-assessed clean energy (PACE) taxation districts, revolving loan funds, energy savings performance contracting (ESPC), and utility on-bill financing. The federal funding would be tailored to best meet the needs of local conditions, by allowing states to define the financing mechanisms they will support. Overall, however, each of the state programs would support the common goal of reducing the cost of capital for improvements to energy efficiency and repayment of costs through energy savings. In addition, DOE could attach intergovernmental conditions to the funding, such as the lifting of regulatory barriers to PACE, on-bill financing, and ESPCs, that would allow for the opening of additional venues for finance.

Building on programs in the Office of Weatherization and Intergovernmental Affairs (OWIP), DOE could provide guidelines and additional technical assistance for the preferred mechanisms. State and local governments are in a strong position to adopt and implement financing programs with local institutions for local economic development needs. The National Governors Association notes that for programs promoting energy efficiency in commercial buildings, "States may need to offer technical assistance to explain financing options and help streamline the application process. They may need to include options for lease situations, to allow repayment transfer to future occupants" (Saha, Gander, and Diekers 2011). DOE could oversee and support any program that brings down the cost of capital for commercial building owners and operators to save energy and pay back the costs through reduced energy expenditures. The highlighted programs listed below are financially sustainable with limited seed funding, include high levels of private leveraging, low-cost to the federal treasury, and adaptable to local political and economic situations.

- **Loan Loss Reserves**
  State and local governments can work with banks to create a loan loss reserve (LLR) fund. Such funds protect financial institutions, as they cover the risk of potential losses through default. An LLR operates through a third-party and does not require a guarantor.

Typically, about 10% of the value of a loan would sit in escrow as a guarantee against loss or default (MacLean, 2010).

- **PACE Financing**
  Tax lien financing through PACE taxation districts allows property owners to finance energy-related upgrades through debt assessed to real estate. This debt is repaid through the property taxes collected by municipal governments. PACE financing operates through municipal bond sales, the proceeds of which go to finance energy upgrades. Burgeoning commercial PACE efforts could be bolstered by enabling federal legislation and a federal LLR or loan guarantee program. Federal legislation would allow PACE financing to be offered in every state and grant PACE bonds tax-exempt status. An overlapping federal LLR or loan guarantee program would offer significant insurance for investors. The elements of this proposed federal policy option are shown in Figure 1.

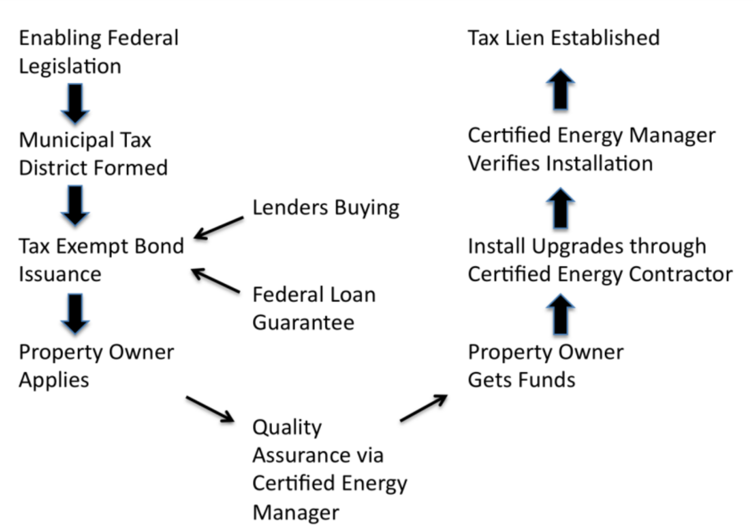

Figure 1. Elements of Clean Energy Tax Lien Financing
Source: Brown et al., 2011

- **Revolving Loan Funds**
  Revolving loan funds provide the upfront costs to commercial sector entities to pay for energy efficiency retrofits and then utilize the repayments through energy savings to continue the financing in perpetuity. The National Association of State Energy Officials (NASEO) database shows that states operate over $925 million in revolving loan funds for all sectors. While some of these programs are new, others have existed since the 1970s. The LoanSTAR program in Texas, for example, has made loans for over two decades, financing 202 projects, none of which have defaulted (NASEO, 2011). This mechanism has a history of success and facilitates long-term growth in energy efficiency through the provision of sustainable, upfront capital.

- **Energy Savings Performance Contracting (ESPC)**
  ESPC agreements are particularly popular in the municipal, university, school, and hospital (MUSH) market. Under an ESPC the building owner contracts with an Energy

Service Company (ESCO) for 10 to 20 years and can repay the initial costs as the savings accrue. These contracts have not been particularly popular in the private and non-profit sectors because of financial regulations and ESCOs' preference for large projects under ESPCs. ESPCs, however, often include guaranteed savings from the ESCO and have been in place, with success, for over three decades (Kats et al., 2011). State and local governments can provide regulatory, technical, and financial assistance to mitigate risk, provide helpful information to consumers, and seed new ESPC initiatives.

- **On-Bill Financing**
  "On-bill financing generally refers to a financial product that is serviced by, or in partnership, a utility company for energy efficiency improvements in a building, and repaid by the building owners on his or her monthly utility bill," according to the American Council for an Energy-Efficient Economy (Bell, Nadel, and Hayes, 2011). While these programs require the participation of a local utility (investor-owned or municipal), they also often benefit from support of local governments in terms of legal authority and the initial financing. They provide a stream of revenue to the utility or financing institution and, as part of the utility bill, are not burdensome for the customer where long-term savings outweigh upfront costs.

Table 1 provides a brief summary of the key actors in the implementation of these financing mechanisms. All of these programs can benefit from further public support, even as the long-term public role varies and, over time, the private sector can subsume most of these activities and related expenses.

Table 1. General Elements of Five Financing Programs

Program	Financing Type	Lien Holder	Lender	Repayment Collector
Loan Loss Reserve	Interest Rate/Risk Reduction	Owner	Financial Institution	Financial Institution
PACE Financing	Tax-Based Loan	Property	Financial Institution (Bond)	Municipal Government
Revolving Loan Fund	Public Loan	Owner	Government or 3rd Party	Government (Revolves funds)
Energy Savings Performance Contracting	Loan	Owner	ESCO or Financial Institution	ESCO
On-Bill Financing	Utility-Bill Based Loan	Property or Owner	Utility or Financial Institution	Utility

NOTE: These are the general designs of these programs, but the options are adaptable.

Figure 2 shows how the different financing options might work synergistically to support financial institutions and customers to maximize savings. In all cases, the federal funding is seen as seeding state and local implementation. The state and local programs could, in turn, directly support the financing needs of building owners or could provide assistance by working with financial institutions to create revolving loan funds or LLRs that can offer financing with reduced interest rates to building owners. Direct financing assistance to building owners could be provided through secured loan funding via PACE, revolving loans, ESPCs, or on-bill programs. Multiple programs can feed off one another to further move the market and support the different interests of financial institutions and commercial properties within communities. With this flexible approach, state and local governments will be able to match the program to local environmental and economic conditions to serve the needs of their community's building owners, businesses, and citizens.

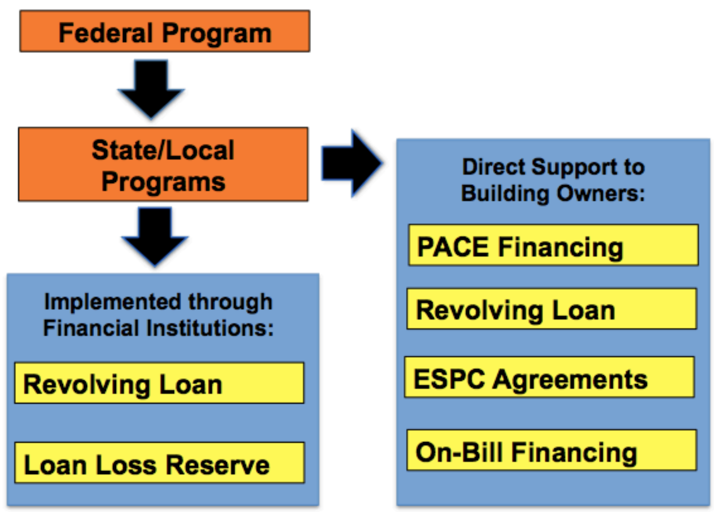

Figure 2. Financing Program Administration

With any financial assistance program, free ridership is a concern because of its impact on cost-effectiveness. As Jaffe, Newell, and Stavins (1999; 2005), EPA (2008) and others have suggested, government and utility company subsidies and tax rebates can require substantial public expenditures per unit of energy savings since consumers who would have purchased the product even in the absence of the subsidy will still receive it. Ideally, the policy should target building owners who would not have installed the energy-efficiency measures without the influence of the program (NAPEE, 2007a, b). However, inevitably some owners are "free riders" because they would have installed the same energy-efficiency measures at the same time whether or not the policy existed. In other instances owners may be only partial or deferred free riders because they would have installed less-efficient measures or would have installed them at a later time. The existence of free riders reduces the estimation of energy savings that might otherwise be attributed to an energy-efficiency policy or program.

Free ridership is likely to be greater for technologies that already have a significant market share, and less so for very new technologies that are relatively expensive. Scarce resources should be focused on promoting types of technologies with the greatest need for a public role, at levels that have the greatest impact per dollar of subsidy. In a time of fiscal constraints on public spending, this suggests the need to develop highly targeted and dynamic designs for financing policies and tax rebates.

Estimates of free ridership are wide ranging. An analysis of federal tax credits for energy-efficient technologies between 1978 and 1983 estimated free ridership to be 93% (Carpenter and Chester, 1994). This rate was reduced by limiting federal tax incentives since 2005 to only the most energy-efficient technologies with less than 5% of the market share (Gold and Nadel, 2011). Based on survey research, a 2006 study of an Oregon residential tax credit estimated free ridership rates of 53% for heat pumps and 60% for gas furnaces (Itron, 2006). The magnitude of free riders for these various circumstances is difficult to predict and has been understudied.

In an effort to dynamically optimize a flexible innovative financing program – considering issues of balance between alternative financing approaches while maximizing leveraging and minimizing free ridership – DOE could establish an oversight organization, analogous to a board of directors. The organization could include public and private stakeholders who would be appointed to review all aspects of this program and provide feedback to DOE. It would encourage further public-private partnerships between local governments, financial institutions, and the commercial sector. The board would be able to conduct a study to see how this program impacts property values for commercial real estate, a key research need in expanding information availability for consumers of energy efficiency products and services. In addition, DOE and the board would be able to provide education and training materials to lending institutions on financial risk mitigation for energy efficiency. DOE would also provide technical assistance and support to national and regional efficiency organizations to facilitate financing through partnerships. These efforts could build on existing mechanisms, including DOE's State Energy Advisory Board and programs in OWIP. Finally, the federal government could further aid in the administration through bulk purchase agreements and other broad levers to improve the marketplace for efficient technologies.

2.1 Policy Experience of State and Local Financing Programs

Innovative financing programs for commercial properties exist in jurisdictions across the country and across the globe. Bellingham/Whatcom County, Washington, and the state of Michigan (Michigan Saves) have created LLRs to bring down the cost of capital improvements and reduce the risk for financial institutions supporting energy efficiency upgrades. The Southeast Energy Efficiency Alliance (SEEA) plans to use funds for the Better Buildings Initiative to develop loan loss programs in several cities in the region (BLT Sustainable Energy, Inc. and Environmental Finance Center, 2011).

Many states passed legislation enabling the creation of PACE districts between 2008 and 2010, as shown in Figure 3. The bulk of the created PACE districts enable residential upgrades; however, these programs were largely brought to a halt in 2010 when Fannie Mae and the Federal Housing Finance Agency stopped supporting the programs and advised banks to do the same. Their concerns were rooted in the fact that the property tax burdens are generally senior to mortgages, and thus PACE debts would be serviced prior to mortgage debts, should a home undergo foreclosure.

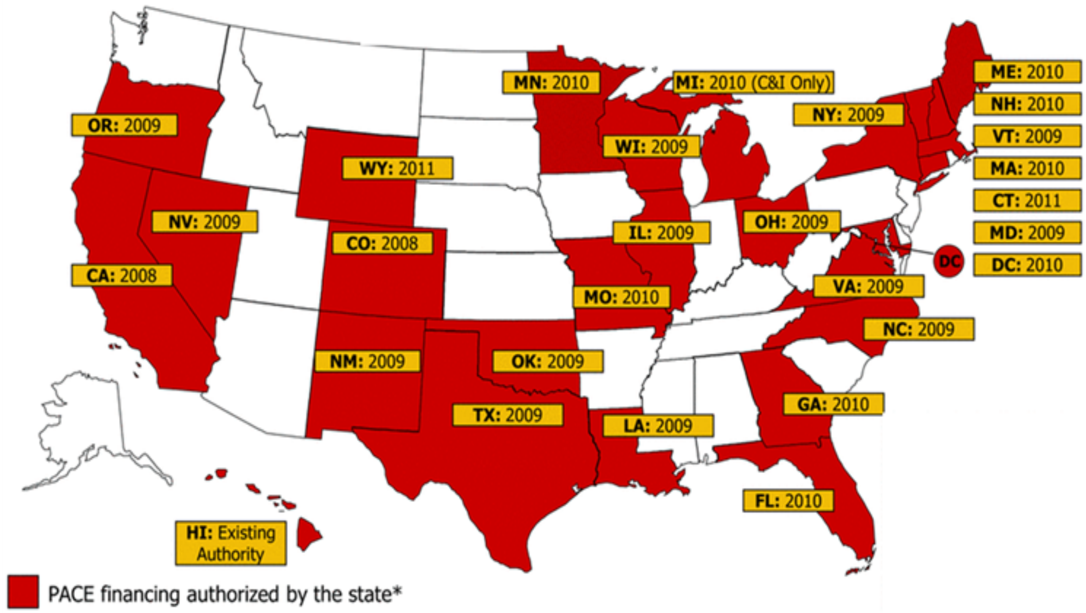

Figure 3. PACE-Enabled States
Source: DSIRE.org

Similar actions have been taken by the Office of the Comptroller of the Currency in the commercial sector, but no group has the influence of a Fannie Mae in this area. Some municipalities have thus switched their focus to the commercial and industrial sectors for PACE programs, resulting in financing for 71 projects through March of 2011 in four municipalities; 13 programs were expected to be operational by the close of 2011 (LBNL and CCI, 2011). A program evaluation for the National Renewable Energy Laboratory (Goldberg, Cliburn, and Coughlin, 2011) notes that Boulder County, Colorado, for example, has achieved significant economic and employment benefits through PACE while Fuller, Portis, and Kammen (2009) show that the Berkeley FIRST program could drive savings across the country if used as a clean energy municipal financing model.

Additionally, 34 states have revolving loan funds (NASEO, 2011). State and local governments have expanded programs and capacity through the Recovery Act, with about $650 million in State Energy Program (SEP) projects in 35 states dedicated to revolving loan funds. While this funding has expired, the partnerships and relationships between stakeholders could continue to yield worthwhile opportunities. In fact, a Lawrence Berkley National Laboratory study estimates that the funds could finance $150-200 million per year over the next 20 years (Goldman et al., 2011). These funds are varied, adaptable, and available for large projects. The Pennsylvania Green Energy Loan fund, for example, chooses interest rates (between 4% and 6.5%) and lengths of term on a project-by-project basis (Sciortino, 2011).

ESCO and utility financing programs also have a history of success. ESPCs are particularly strong in the MUSH market. The Kansas Facility Conservation Improvement Program, for example, has made over $130 million in energy-efficient improvements through ESPCs, saving $11 million per year in energy expenditures while reducing the state's carbon footprint (NASEO, 2008). Under the ESPC agreement, the ESCO guarantees the savings and provides financing, with the company (or institution) accruing some of the measured and verified financial savings over the life of the project (Zobler and Hatcher, 2003). On-bill financing opportunities through utilities are also expanding, as shown in Figure 4 and, despite a variety of implementation barriers in the commercial sector, energy savings have expanded with minimal defaults (Bell, Nadel, and Hayes, 2011).

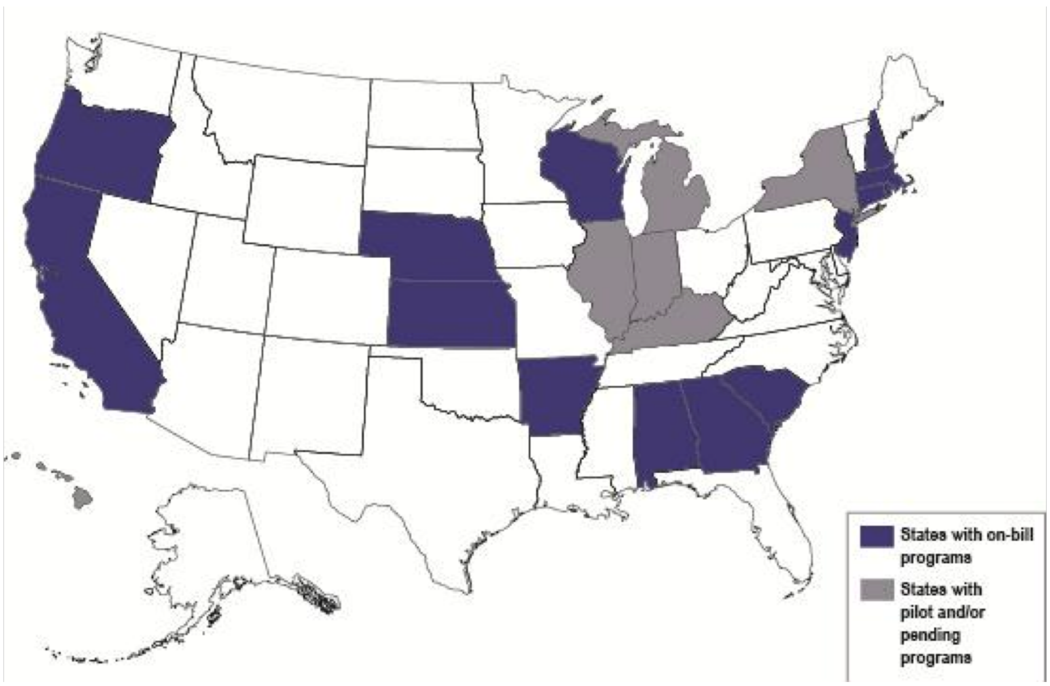

Figure 4. States with On-Bill Financing Programs
Source: Bell, Nadel, and Hayes, 2011

Despite the recognition that deep energy-efficiency upgrades are achieved most effectively with comprehensive approaches, most financing programs to date have focused on supporting individual energy-efficiency measures. One reason for this may be the greater experience and successes to date with the more limited measure-by-measure approaches. A recent international review of financial incentives for energy-efficient retrofits in buildings suggests that it is more difficult to motivate comprehensive retrofits than it is to spur investments in individual retrofit measures. Countries have generally experienced success only with the financing of individual measures even when they have offered similar levels of support for both comprehensive and single measures (Neuhoff et al., 2012). Another reason may be the lower transaction costs including the cost of measuring and verifying program impacts.

2.2 Rationale for Federal Involvement

This policy would provide an opportunity for the federal government to maintain support to state and local governments after the Recovery Act resources expire in 2012. State governments received $3.1 billion in stimulus funds through the SEP, while state and local governments received $3.2 billion through the EECBG; in the next fiscal year, they will likely receive well below the authorized SEP level ($125 million) and no funding for EECBG. This flexible innovative financing policy option could build on established mechanisms in DOE, expanding relationships between the OWIP, state energy offices, and local governments from ARRA funding. Public-private partnerships would also aid in administration.

State and local governments have positioned themselves as leaders in this policy arena (Rabe, 2011). A flexible innovative financing program blends the benefits of local action and federal oversight and resources through a polycentric approach, taking advantage of the multiple layers of governance. The program could benefit from the innovation and accountability of the local level implementers. Competition can also serve as a program driver to push local officials and businesses to invest for economic development and civic pride. Kansas, for example, has used ARRA funds to build a friendly competition among sixteen cities (Sciortino, 2011). The potential program could also, however, have the advantage of a degree of consistency and the economies of scale that federal intervention and purchase agreements can provide, particularly in making bonds and other financial products more economically and administratively efficient (Kammen, 2009). As with other climate and energy programs, the polycentric nature of this activity can meet the local challenges of these international policy problems (Brown and Sovacool, 2011). Federal resources and support can facilitate state and local capacities to improve clean energy programs for commercial building efficiency and expand other related capabilities for technology deployment activities.

2.3 Market Barriers and Failures Addressed

Investment capital for commercial facilities has become a scarce resource in light of the global financial crisis, preventing the achievement of cost-effective energy savings. ARRA programs missed much of the opportunity in private buildings. Half of SEP funding for energy efficiency in the states (approximately $750 million of the $1.5 billion), for example, went to the public building stock, with the rest going to residential, commercial, and industrial facilities (Goldman et al., 2011). In order to have a fully functioning market, consumers must be fully rational cost-minimizing and profit-maximizing actors with complete information on costs and benefits (Brown and Sovacool, 2011). The fact that commercial facilities are missing out on cost effective investment due to financing challenges justifies government intervention.

Financing policies can help overcome the capital market failure of liquidity constraints in firms. In addition, while energy-efficient equipment is a capital cost, energy bills are an operating cost, leading to challenges in budgeting for upgrades and retrofits (Gillingham, Newell, and Palmer, 2009). Tying repayment into taxes or utility bills through innovative financing mechanisms, however, can allow firms to adjust their cost structures and consider the upgrades as an operational savings rather than a capital expenditure.

In addition, there is a significant challenge in uncertainty, as financing projects have had mixed results and firms cannot always be sure of future savings. Implicit discount rates of firms tend to be high for calculating the potential benefits of future savings (Gillingham, Newell, and Palmer 2009). In the commercial sector, the discount rate corresponds with the opportunity cost of capital. As a competing option among a multitude of investment choices, businesses are looking for a greater than average return on investment from clean energy projects (Short, Packey, and Holt, 1995). Cost reductions and information dissemination through program partners could serve to make energy efficiency benefits more competitive for decision-makers, particularly firms concerned with rising energy costs and uncertainty over carbon regulations.

Reducing upfront costs and improving knowledge on the subject of energy efficiency financing will overcome many but not all barriers. For example, ESCOs may ignore efficiencies beyond the lowest hanging fruit, as their incentive is to pursue the most obviously cost-effective options, which could miss the full suite economically attractive efficiency investments (Schewel et al., 2009). Federal, state, and local oversight and partnerships can help alleviate further issues. In addition, this policy will not mitigate all risk. Efforts to quantify and potentially insure projects can improve understanding and help manage risk (Mills et al., 2006). National protocols on measurement and verification can aid in program and project evaluation, mitigating risk to investors, and allowing for dissemination of verified successes.

2.4 Political Feasibility

The White House (2011) has looked to encourage state and local activities in the Better Buildings Initiative (BBI) through competitive grant programs. DOE through BBI has already opened resources and encouraged leveraging partners. On the other hand, Congress may be skeptical of such efforts, particularly in light of the default of Solyndara (Restuccia and Geman, 2011). Efforts to reduce spending will also make passage and appropriations for this financing more difficult. This program option, however, could limit federal costs and liabilities as loans, loan guarantees, and loan repayments would occur at the state and local level through the private sector. DOE has supported WHEEL to bring significant resources through innovative financing into the residential energy efficiency market through state and local government (Shreve, 2012), and may support similar options in other sectors of the energy consumption economy.

This policy option could garner support from implementing jurisdictions. A survey of the US Conference of Mayors indicates that local-level executives consider financing as the most significant barrier to energy efficiency deployment in their communities. Mayors report that 94% of their cities consider energy efficiency as an important goal of their energy strategies, express optimism about the expansion of these activities in municipalities, but are in need of funds to achieve full deployment (GlobeScan Inc., 2011). In addition, the National Governors Association has created guidance documents for its membership to expand clean energy financing options (Saha, Gander, and Diekers 2011). While this program would require leveraging from cash-strapped states and local governments, it would also serve to help them achieve their ambitious climate and energy goals. The financing could foster economic development, both in the energy efficiency services sector as well as in the commercial sector through reductions in the cost of doing business. Partnerships among all levels of government and the private sector could spread the burden and risk, making this policy option attractive to multiple stakeholders seeking low-cost and proven energy and environmental outcomes.

2.5 Complementary Policies

This federal financing option could expand and enhance other commercial building activities. Complementary regulatory and information policies can support the impetus of commercial building owners and operators to seek financing options. Owners and operators of properties that undergo retrofits will achieve additional benefits with regards to property values from the financed investment with labeling of the building energy efficiency. In addition, new construction may be eligible for additional resources for code-compliance or efforts to build beyond the energy code. Low-cost capital and procurement policies can facilitate a broad, national strategy for commercial energy efficiency.

"In the commercial, residential, and end-user sectors, the goal is to use the financial incentives to educate the public on benefits of energy efficiency and increase market penetration of existing efficient technologies," notes a National Renewable Energy Laboratory analysis of energy policy trends (Doris, Cochran, and Vorum, 2009). Thus, this policy option would have improved effectiveness when combined with public awareness and building labeling programs. Improved standards and technologies would also allow this program to achieve further savings. This policy option would also require an expanded pool of skilled labor to install and retrofit the technologies. While this is a benefit in these times of high unemployment, workforce development policies are necessary to implement these programs nationwide.

Carbon tax analyses notes that a price on carbon is not a complete solution to the climate challenge (Brown, Cox, and Sun, 2012a, b). In addition, analyses of financing programs indicate that financing programs can benefit from a price on emissions (Fuller, Portis, and Kammen, 2009). While both policies can exist on their own, they also can complement one another to achieve greater savings. It is also worth noting that the intention and modeling of this policy does not exclude additional tax credits, subsidies, or additional incentives. This financing can supplement rather than supplant existing federal, state, and local policies in the commercial sector.

3. Methodology for Modeling the Impacts of Flexible Innovative Financing

The Georgia Institute of Technology's version of the National Energy Modeling System (GT-NEMS) is the principal modeling tool used in this study to examine the likely impacts of a flexible innovative financing policy. After describing this modeling tool, we explain how it is used to characterize the impacts of a flexible innovative financing policy. This includes describing the technologies to be subsidized and the magnitude of the subsidy to be modeled.

3.1 The Georgia Tech-National Energy Modeling System

GT-NEMS is based on the National Energy Modeling System (NEMS) that generated the Energy Information Administration (EIA)'s *Annual Energy Outlook 2011* (EIA, 2011). This energy outlook, which EIA produces each year for the US, forecasts energy supply and demand for the nation out to 2035. It is the principal modeling tool used to forecast future US energy supply and demand, and its business-as-usual forecast is the Reference case for our analysis of alternative policy scenarios.

Twelve modules represent supply (oil and gas, coal, and renewable fuels), demand (residential, commercial, industrial, and transportation sectors), energy conversion (electricity and petroleum markets), and macroeconomic and international energy market factors. A thirteenth "integrating" module ensures that a general market equilibrium is achieved among the other modules. Beginning with current resource supply and price data and making assumptions about future consumption patterns and technological development, NEMS carries through the market interactions represented by the thirteen modules and solves for the price and quantity of each energy type that balances supply and demand in each sector and region represented (EIA, 2009).

Outputs from GT-NEMS are intended as forecasts of general trends rather than precise statements of what will happen in the future. As such, GT-NEMS is highly suited to projecting how alternative assumptions about resource availability, consumer demand, and policy implementation may impact energy markets over time. In addition to examining the *AEO* Reference case as our baseline forecast, we use an updated version of the GT-NEMS Reference case to provide a updated forecast. GT-NEMS uses a combination of discount rates and the rate for US government ten-year Treasury notes to calculate the consumer hurdle rates used in equipment purchasing decision-making. While the macroeconomic module of NEMS determines the rate for ten-year Treasury notes endogenously, the discount rates are inputs to the model. Based on a review of the literature reported in Cox, Brown, and Sun (2012), we concluded that these discount rates are unrealistically high. Using the methodology developed by Cox, Brown, and Sun (2012a, b), these discount rates are revised for six energy end-uses (lighting, refrigeration, heating, air conditioning, water heating, and cooking), thereby providing an updated reference case.

The GT-NEMS "bottom-up" engineering and economic modeling approach is well suited to a financing analysis focused on understanding the likely response of the commercial buildings sector (Cullenward, Wilkerson, and Davidian, 2009). By characterizing nearly 350 distinct commercial building technologies, and by enabling the separate analysis of all nine Census divisions, ten end-uses (e.g., lighting and air conditioning), and eleven building types, GT-NEMS offers the potential for a rich examination of policy impacts. Top-down modeling of the energy economy produces fewer insights about the role of specific technologies and detailed end-use effects (Energy Modeling Forum, 2011). In addition, we use the suite of technologies from EIA's "High Tech" side case that assumes higher efficiencies for equipment, as well as lower costs and earlier availability of some advanced equipment. Use of the high-technology case in GT-

NEMS is predicated on the presumption that creating flexible innovative financing would facilitate research, development, and the demand for better-than-baseline technologies.

3.2 Assumptions Regarding the Impacts of Flexible Innovative Financing

GT-NEMS does not offer a direct lever for modeling the impact of financing options for energy efficiency. As a result, the research team has modified GT-NEMS to reflect the impacts of this policy option as described below. The upfront financial impact and technology choices required justifiable assumptions about how this policy might look in the marketplace for input into the microeconomic general equilibrium model.

A fundamental assumption of this analysis is that flexible innovative financing could be modeled as a subsidy on the first costs of energy-efficient technologies as firms consider the net present value of an investment. Reducing interest rates, entering into ESPCs, or financing through the other mechanisms have the long-term impact of making upfront investments more economically attractive. Appendix B shows how different financing policies compare, based on the example of a simple lighting replacement policy.

3.3 Technologies to be Subsidized

To model flexible innovative financing in GT-NEMS, we must identify the technology portfolio that we would subsidize through reduced first costs. We began by examining the same energy-efficient technologies that saw demand growth under the carbon tax analysis of Brown, Cox, and Sun (2012a, b). In the carbon tax analysis, we evaluated the building technologies in the EIA Reference case as well as the suite of building technologies from EIA's "High Tech" side case. Using that larger portfolio of technologies, the addition of a carbon tax resulted in a set of 110 technologies experiencing demand growth. Incentivizing this set of 110 technologies from the carbon tax analysis has two key benefits for this research. First, we are subsidizing energy-efficient technologies that the market would choose under the condition of rising energy costs due to emissions pricing. Second, we can evaluate how a financial subsidy compares in its effectiveness with a carbon tax in terms of driving the market for low-carbon technologies. This can help policymakers understand different mechanisms to achieve the goals of advanced technology deployment in the economy of the commercial sector.

This set of 110 technologies experiencing demand growth under the carbon tax included 11 space heating technologies, 28 space cooling technologies, seven water heating technologies, five ventilation technologies, two technologies for cooking, 10 lighting options, and 47 refrigeration technologies. Altogether, these 110 technologies represent 31% of the 350 technologies characterized in the High Technology case of GT-NEMS. After preliminary analysis of this set of subsidies, we concluded that the inclusion of all 110 technologies had at least three disadvantages:

- The ENERGY STAR® Program generally gives its label only to the most efficient 20-25% products. Thus, subsidizing 31% of available technologies exceeds that benchmark.
- The 110 technologies selected by the carbon tax policy include several technologies that were only slightly more efficient than "typical" technologies of the same type. For

example, three lighting technologies received more service demand when modeling a carbon tax, but so did three similar, but more efficient technologies. One of these technologies – fluorescent 96 bulbs with a T8 ballast – had one model with 95.10 luminous efficacy (lumens/watt) compared to a second model with a 76.90 luminous efficacy. They both entered the market in 2003 and were available throughout the planning horizon. The less efficient model was more expensive, so it would be counterproductive to subsidize it. Similarly, two reciprocating chillers are introduced into the NEMS technology suite in 2020 and last throughout the planning horizon. One has a coefficient of efficiency of 3.20 with an average cost of 38.7, and the other has a COP of 3.63 with an average cost of 42.08. The service demand for both technologies grew in the carbon tax analysis, but we concluded that it was not appropriate to subsidize the less efficient and more "typical" reciprocating chiller.

- Possibly due to the inclusion of so many technologies that were only slightly more efficient than more "typical" alternatives, subsidizing 110 technologies resulted in less energy savings than subsidizing the subset of more efficient 64 technologies. Specifically, a 10% subsidy applied to the 110 technologies produced an energy savings of 2.8% for 2035 and had a benefit/cost ratio of 1.0. In contrast, a 10% subsidy applied to the 64 technologies raised the energy savings to 3.8% for 2035 and raised the benefit/cost ratio to 1.4 (Table 2). A portion of the energy savings for both of these cases can be attributed simply to the inclusion of a larger suite of energy-efficient technologies from EIA's "High Tech" case, which reduced energy consumption in commercial buildings by 0.9% in 2020 and 1.4% in 2035, without the inclusion of any subsidies.

Table 2. Number and Level of Technology Subsidies

Savings in Delivered Energy	High Tech Reference Case	110 Technologies Subsidized				64 Technologies Subsidized
	0% Subsidy	5% Subsidy	10% Subsidy	20% Subsidy	30% Subsidy	10% Subsidy
2020	0.9%	1.8%	2.2%	2.2%	2.2%	2.4%
2035	1.4%	2.8%	2.8%	3.3%	4.0%	3.8%
Benefit/Cost Ratio			1.0			1.4

3.4 Timing and Level of Subsidy

We assume that the flexible innovative financing policy would be fully implemented in 2015. Presumably it would be announced in 2013 or 2014 to enable program managers and stakeholders to prepare for implementation. In reality, the announcement of a forthcoming program might cause commercial building owners to delay investing in energy upgrades so that they would qualify for financial assistance in 2015. We are unable to model such an "announcement effect" in GT-NEMS.

The level of technology subsidy is another variable that influences the impact and effectiveness of a financing program. On the one hand, higher subsidies generally motivate more investment and have a larger impact on consumer behavior than lower subsidies (Hassett and Metcalf, 1995). On the other hand, high subsidies are generally more costly to the government and may have higher rates of free ridership.

Including all 110 technologies, we used GT-NEMS to estimate the energy savings that various levels of subsidy would likely produce. Energy savings is measured as the difference between the delivered energy consumed by commercial buildings in the Reference case compared with a case in which the chosen technologies have a lower first cost due to the subsidy being examined.

Table 2 reports the energy savings estimated for 2020 and 2035. The magnitude of energy savings was estimated to increase in 2020 from 1.8% with a 5% subsidy to 2.2% with a 10%, 20%, or 30% subsidy. Thus, in the short-run the impact of tripling the level of subsidy would only modestly increase the savings from a 5% subsidy. In the year 2035, the energy savings are estimated to increase from 2.8% with a 5% subsidy to 4.0% with a 30% subsidy.

From this analysis we concluded that a 10% subsidy was meritorious because it could quickly achieve a significant level of savings that would likely increase over time. When applied to the smaller set of 64 incentivized technologies, GT-NEMS analysis estimates that the energy savings could grow from 2.4% in 2020 to 3.8% in 2035.

3.5 Analysis of Input Assumptions

To justify assumptions about the policy option's ability to mimic a financial subsidy, we conducted a spreadsheet analysis to examine the impact of financing. Below are the inputs and assumptions needed for the analysis:

- Energy costs and savings (using baseline prices and technology profiles).
- Bulk discounts on energy efficiency equipment.
- Discount rate
- Interest rate (Lower rates through policy)
- Payback period
- Length of loan (Based on type of financing).

Appendix B shows the results of spreadsheet analysis on lighting that indicates that the impact of these programs is similar to a subsidy on up-front costs in the GT-NEMS model.

4. Results

We first present the estimates of commercial building energy consumption with financing options. The discussion is followed by the policy impacts on energy prices and expenditures, and CO_2 emissions from commercial buildings. We then turn to the changes in commercial energy end-uses and the technology shifts that underpin the policy impacts. Following an analysis of the pollution and carbon emission reduction benefits of the financing policy, we summarize the national policy impacts using benefit/cost analysis. We then compare the impacts of flexible innovative financing across all nine Census divisions and eleven types of buildings and with the carbon tax policy examined by Brown, Cox, and Sun (2012a, b).

4.1 Impacts on Commercial Energy Consumption

GT-NEMS modeling suggests that commercial building owners and tenants would respond quickly to financing programs when they are first offered in 2015. Almost half a quad of energy would be saved in 2020, representing a reduction of 2.6% of the energy consumed by commercial buildings. Over time, the financing policy would generate increased energy savings for commercial building owners and tenants, achieving 1.04 quads of savings in 2035, equivalent to a 4.3% reduction in the energy consumed by the commercial buildings sector.

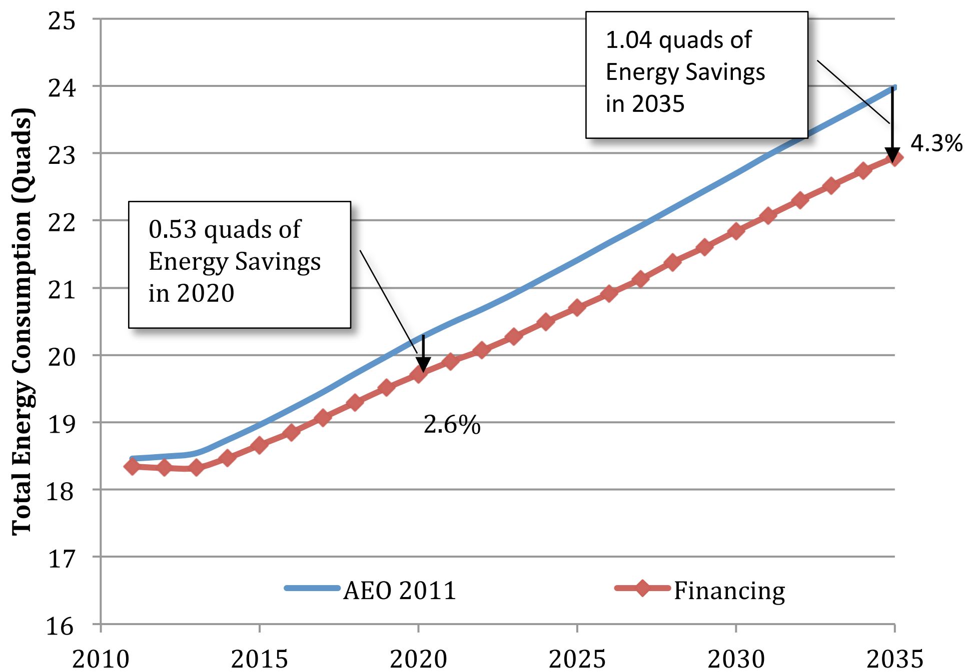

Figure 5. Commercial Energy Consumption: Innovative Financing Scenario versus Reference Case

Table 3 shows the energy consumption reductions in the commercial sector from natural gas and electricity. The reduction in electricity consumption and electricity-related losses is the dominant impact, accounting for an increasing proportion of the savings over time, as primary energy savings increase significantly for both ventilation and lighting. Specifically, the innovative financing policy is estimated to cut natural gas consumption by 3.1% in 2020 but by only 2.4% in 2035. In contrast, electricity savings rise from 2.7% in 2020 to 5.1% in 2035.

The innovative financing policy would reduce energy consumption without shrinking the commercial sector's growing spatial footprint. As a result, energy intensity, measured in Btu per ft^2, declines, as does the nation's energy intensity as a whole (Figure 6).

Table 3. Innovative Financing Policy's Impact on Commercial Energy Consumption

Commercial Sector Energy Use		Natural Gas	Electricity	Electricity Related Losses
2020	Reference	3.58	5.20	10.71
	Innovative Financing Policy	3.48	5.07	10.45
	Energy Savings (Quads)	0.11	0.14	0.28
	% Change	-3.1%	-2.7%	-2.6%
2035	Reference	3.92	6.43	12.93
	Innovative Financing Policy	3.83	6.1	12.31
	Energy Savings (Quads)	0.09	0.33	0.62
	% Change	-2.4%	-5.1%	-4.8%

The impact on the energy intensity of the nation is proportionate to the percentage of the national energy budget that is consumed by commercial buildings. For example, in 2020, energy use per square foot of commercial buildings space reduces by 2.6%, while energy use per GDP declines by only 0.5%. While significant, this improvement is 17% short of the Better Buildings Initiative goal of a 20% improvement over 2020 energy intensities in the commercial building sector. Thus, financing policies such as the one modeled in this paper would be unlikely to meet the Better Buildings Initiative goals without further policy interventions.

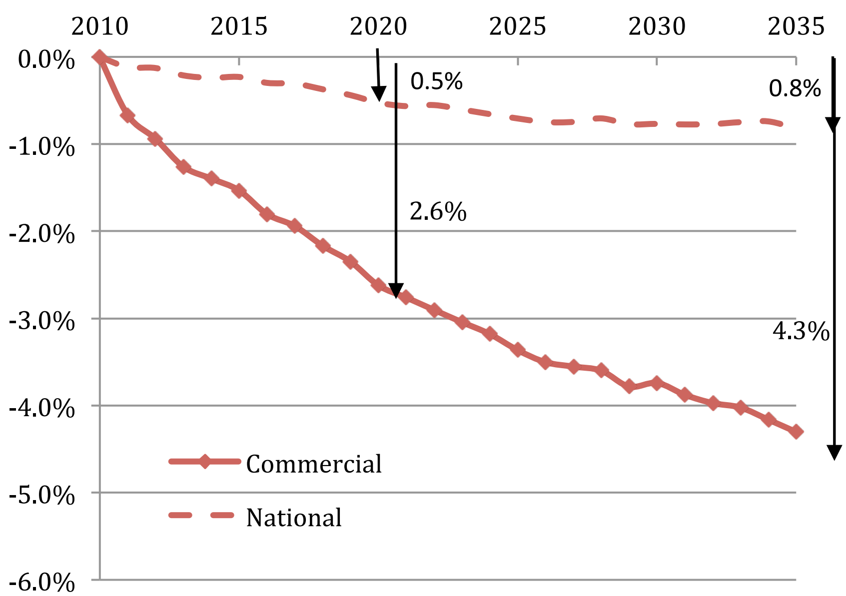

Figure 6. Financing's Impacts on the Energy Intensity of the Commercial Buildings Sector and the Nation

4.2 Impacts on Energy Prices and Energy Expenditures

The innovative financing policy is estimated to reduce natural gas consumption and electricity consumption. The reduction in natural gas demand would drive natural gas prices notably and consistently lower than the Reference case after 2020 (the price decrease is about 1.3% in 2035). This, in turn, results in a rebound effect as consumers respond to the ability to purchase more natural gas.

The larger electricity savings has a more modest and variable effect on electricity rates (Figure 7). The differences in electricity prices between the Reference and policy cases are smaller than 0.7% for all years. Electric rates in the policy case exceed the Reference rates from 2021-2026, and from 2029-2031. In 2035, The Reference price is 9.22¢/kWh, while the policy case price is 9.21¢/kWh.

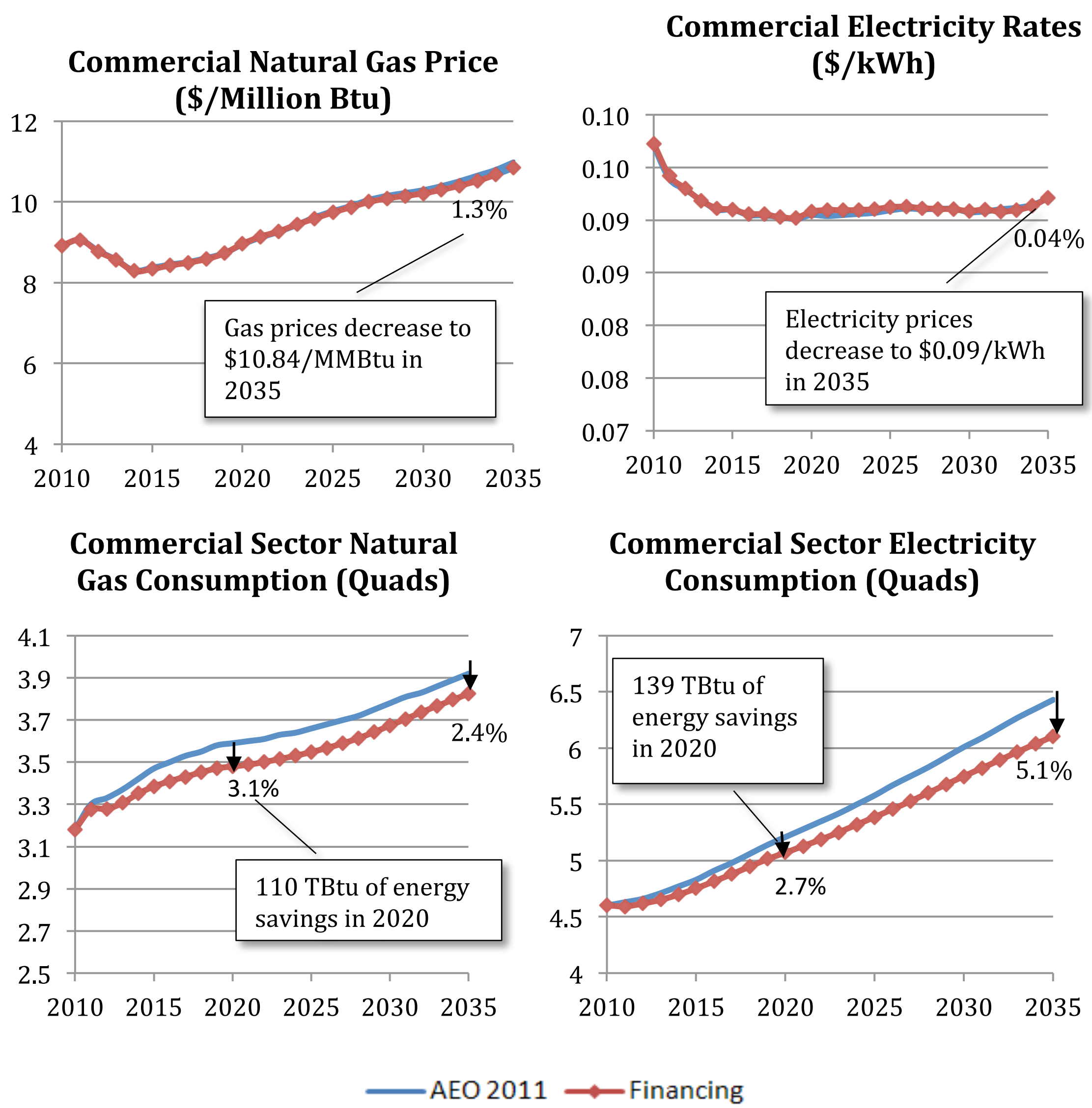

Figure 7. Commercial Sector Natural Gas and Electricity Rates and Consumption: Innovative Financing Policy Versus Reference Case

(Percentage numbers are with respect to the *AEO 2011* Reference case in the same year)

The impact of financing programs on energy bills paid by commercial building owners and tenants is the multiplicative effect of reduced energy consumption and lower fuel prices. Figure 8 summarizes the savings in energy expenditure in the commercial sector. Savings in energy expenditures are estimated to be $4 billion in 2020, rising to $10.4 billion in 2035 – a 4.5% reduction from the Reference case. Using a 3% discount rate, the net present value of the accumulated energy savings by 2035 totals $91 billion (Table 4).

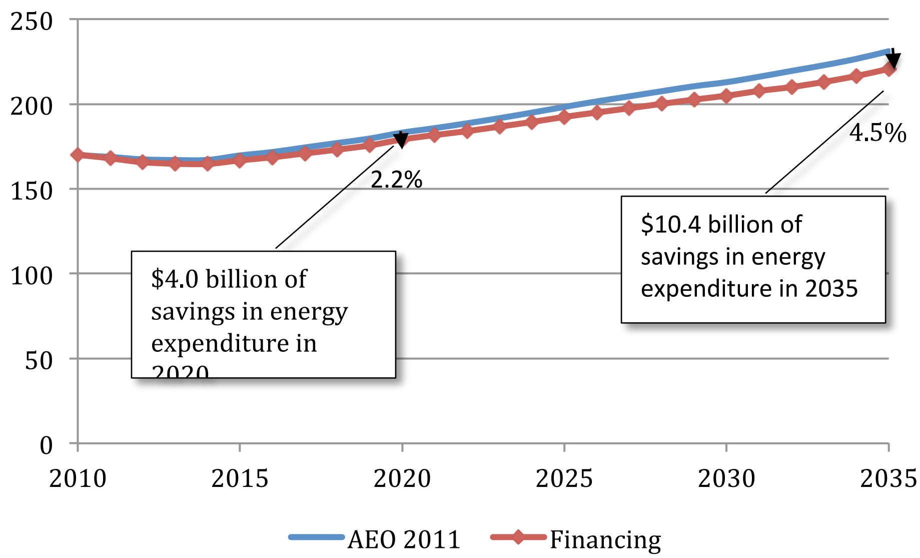

Figure 8. Commercial Sector Energy Expenditures (in Billions 2009$)

Table 4. Energy Expenditures (Billion 2009-$)

Year	Decrease in Energy Expenditures: Annual	Decrease in Energy Expenditures : Cumulative*
2020	4.0	24.1
2035	10.4	90.9

*Presented values at calculated using a 3% discount rate

4.3 Impacts on CO_2 Emissions from Commercial Buildings

Compared with the Reference case forecast, the innovative financing option is estimated to produce a drop in total commercial sector CO_2 emissions of 2.8% in 2020 rising to 4.2% in 2035 (Figure 9). Emissions would continue to rise in both the Reference and policy cases, but the increase would be smaller if an innovative financing policy to promote energy-efficiency investments were implemented. CO_2 emissions from natural gas use and electricity use in the commercial sector would be proportionately reduced with the decreases in energy consumption resulting from a flexible innovative financing policy. This policy option could reduce CO_2 emissions from natural gas use by 2.5%, and emissions from electricity use by 4.8% in 2035.

As percentages, these reductions are close to the energy consumption reductions for each fuel. In 2035, proportionately more electricity is saved (5.1%) than CO_2 emission are reduced (4.8%), reflecting the small shift to lower carbon electricity over time. As expected, the financing option would appear to have little impact on the choice of energy sources for power generation, since there is a relatively small reduction in CO_2 emissions from the national power sector (1.5% in 2035) principally reflecting the lower demand for electricity as a result of the financing policy.

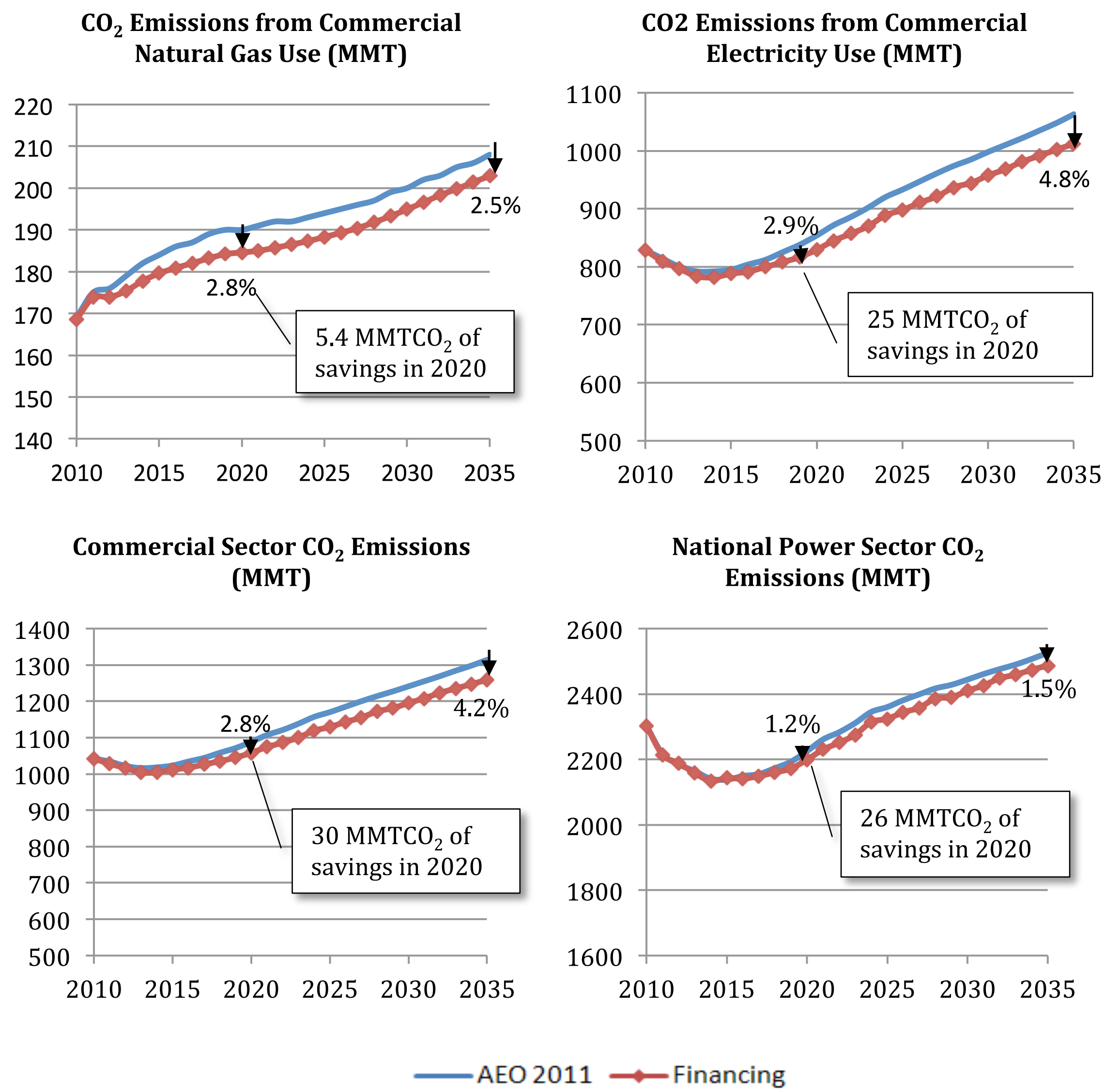

Figure 9. CO_2 Emission Reductions from the Commercial and Power Sectors

4.4 Impacts on Investment Costs and GDP

Under the innovative financing policy, more energy-efficient equipment would be deployed, leading to the significant energy savings shown earlier in this paper. There are, however, costs associated with these investments. GT-NEMS does not directly calculate the capital investment costs to upgrade the end-use equipment including space heating and cooling, water heating and lighting equipment. Nevertheless, it provides the unit cost, coefficient of performance, and capacity factor for each commercial technology and the service demand it fulfills. Based on this information, we developed a spreadsheet analysis tool that calculates the capital investment cost for every end-use technology vintage in the commercial sector and use it to analyze the equipment investment costs under both the Reference and innovative financing scenarios. These estimates of investment costs are derived from the outputs of the GT-NEMS Reference case, High-Tech Case, and Financing policy scenario (specifically, the KSDOUT, KTEK, and KCAPFAC files). GT-NEMS generates estimated investment costs for individual technologies and vintages, and for major end-uses, including space heating, space cooling, water heating, refrigeration, cooking, ventilation, and lighting. Due to questionable results for ventilation, we estimate equipment costs for that end-use by using the ratio of equipment costs to energy savings from space cooling.

Table 5. Equipment Expenditures on Energy-Efficient Technologies (in Billions 2009-$)*

Year	Total in Reference Case: All Techs	Total in High-Tech Case: All Techs	Total in Financing Policy: All Techs	Total in Reference Case: EE Techs**	Total in High-Tech Case: EE Techs**	Total in Financing Policy: EE Techs	Subsidy
2020	52.95	52.23	54.27	6.48	14.42	42.92	4.77
2035	40.06	39.71	41.18	3.76	11.18	34.66	3.85

*Present values were calculated using a 3% discount rate.
**Only 49 of the 64 incentivized energy-efficient technologies are in the Reference Case.

An examination of the total expenditures shown in Table 5 indicates that the innovative financing policy could motivate owners of commercial buildings in the US to invest 2-3% more on purchasing and retrofitting end-use equipment – $1.32 billion more in 2020, and $1.12 billion more in 2035, relative to the Reference case. The High-Tech case results in lower total expenditures on commercial building equipment, presumably because that case assumes lower costs for a set of advanced technologies.

Narrowing the focus to expenditures on the 64 high-efficiency technologies suggests a stronger impact of the Financing policy. In the Reference case, only $6.48 billion is spent on high-efficiency technologies in 2020 (only 12% of the $52.95 billion total investment). This increases modestly to $14.42 billion when the High-Tech case is modeled. In contrast, the Financing policy estimates that $47.7 billion would be spent on the 64 high-efficiency technologies in 2020 ($42.92 billion in addition to the $4.77 billion subsidy), representing a seven-fold increase over the Reference case. Nearly 80% of the total investment in energy equipment in commercial buildings is spent on the 64 advanced technologies. The impacts and subsidies in 2035 are comparable, with a ten-fold increase in expenditures on high-efficiency technologies.

Free ridership remains an issue: some of the technology upgrades that would have occurred in the absence of a subsidy are being incentivized. In 2020, for example, the $6.48 billion spent on high-efficiency technologies would receive subsidies of $720 million. Thus, 15% of the subsidy in that year would be spent on free riders in 2020, dropping to 11% in 2035, which is much lower than indicated by published research to date. The Financing policy was designed to minimize these free rider costs by carefully selecting the technologies to be subsidized and by providing only a 10% incentive.

Turning to the national economy, our GT-NEMS analysis suggests that the innovative financing policy modeled in this study would have limited impact on national GDP. Table 6 illustrates the GDP change between the Reference and the financing policy. The policy could have a modest negative impact on the national economy in the near term with a $3 billion decrease in GDP in 2020. By 2035, the GDP cost is estimated to be $11 billion, representing a 0.04% decrease or a 4-hour delay in the achievement of a GDP of $28.3 trillion (the Reference case forecast for 2035).

Table 6. Commercial Innovative Financing Policy's Impact on National GDP

	2020	2035
Reference (Billion 2009-$)	19,168	28,260
Innovative Financing Policy (Billion 2009-$)	19,165	28,249
Change (%)	-0.01%	-0.04%
GDP Delay (Hours)	1	4

4.5 Changes in Commercial Energy End-Uses

In the updated Reference case, financing programs are estimated to reduce energy consumption in every category of end-use energy consumption in the commercial buildings sector. The energy consumed for ventilation would decrease most significantly, dropping by 42% in 2020 and by 52% in 2035, from 2.2 quads to 1 quad with the shift from constant to variable air volume systems. Overall, the energy required to ventilate commercial buildings in 2035 is less than the energy consumed by ventilation systems in 2010. All of the other end uses shown in Table 7 increase in energy consumption over time, even with the innovative financing option.

Lighting produces the next largest savings, especially after 2020, when high-efficiency LEDs become available. In 2035, electricity for lighting drops by 7% relative to the Reference case, saving 0.3 quads of energy in that year. The energy consumption for space heating in commercial buildings also is estimated to drop significantly compared with the Reference case forecast, while energy consumption for space cooling and water heating would experience smaller reductions relative to the base case. The limited energy savings for space cooling and water heating is somewhat surprising, since 17 space cooling technologies were incentivized by the financing option, along with seven water heating technologies. Energy consumption for "other uses" increase by 0.5 quads (3%) in 2035 relative to the Reference case, and this difference is entirely due to increased electricity consumption. "Other uses" include space heating and refrigeration (which decline in energy use as a result of the financing policy) as well as ATMs, elevators, office equipment, and other devices. This increased consumption may be due partly to a rebound effect from the small drop in electricity prices.

Table 7 illustrates the estimated energy savings by end-use in detail. It provides no evidence that the financing policy causes fuel switching, an issue that will be revisited in our discussion of technology shifts. Altogether, the policy option could stimulate a significant reduction in total energy consumption by commercial buildings.

4.6 Technology Shifts and Commercial Building Equipment Expenditures

The energy efficiency of end-use technologies in the commercial buildings sector is generally measured as a ratio of energy output to energy input, although there are variations across classes of technologies. As shown in Table 8, the flexible innovative financing policy would shift technologies toward greater efficiency. Of particular note, ventilation system efficiencies increase in the first decade, when there is a surge of variable air volume systems, and this trend toward higher efficiency systems continues through 2035. Although lighting efficiencies improve only slightly above the Reference case in the first decade (which is when the 2012-14 lighting standard takes hold), by the second decade, the deployment of LED lighting and super fluorescents increase the average luminous efficacy from 55.9 lumens/watt in the Reference case to 61.5 lumens/watt in the financing policy by 2035. With LED or solid state lighting there are already a variety of product types with variable luminous efficiencies.[1] In GT-NEMS, this technology is estimated to become more cost-effective over time, in both the Reference and the policy cases.

Natural gas space heating as well as electric space cooling and water heating all see average coefficients of performance (COPs) that improve more rapidly over time with the financing option. Electric space heating, on the other hand, declines in average COP, due to a stronger shift to air source heat pumps (ASHPs) compared with ground source heat pumps (GSHPs). While GSHPs have higher COPs, their costs tend to be higher than for ASHPs, and the investment tax credit that subsidized GSHPs today is set to expire in 2016.

[1] See the following DOE website for details:
http://www1.eere.energy.gov/buildings/ssl/sslbasics_ledbasics.html#how_efficient

Table 7. Energy Consumption by Commercial End-Use: Innovative Financing Policy vs Reference Case

End Use	Energy Consumption (in Quads)	2010	2020			2035		
		Reference	Reference	Financing	% Change	Reference	Financing	% Change
Space Heating	Delivered Energy	1.9	2.1	1.9	-5%	2.0	2.0	-5%
	--Purchased Electricity	0.2	0.2	0.2	-4%	0.2	0.2	-7%
	--Natural Gas	1.6	1.8	1.7	-6%	1.8	1.7	-5%
	--Other Fuels	0.1	0.1	0.1	0%	0.1	0.1	0%
	Electricity Related Losses	0.4	0.4	0.3	-3%	0.4	0.3	-6%
	Total Energy	2.3	2.4	2.3	-5%	2.4	2.3	-5%
Space Cooling	Delivered Energy	0.6	0.6	0.6	-1%	0.6	0.6	-2%
	--Purchased Electricity	0.6	0.5	0.5	-1%	0.6	0.6	-1%
	Electricity Related Losses	1.3	1.1	1.1	-1%	1.2	1.2	-1%
	Total Energy	1.9	1.7	1.7	-1%	1.9	1.9	-1%
Ventilation	Purchased Electricity (Delivered Energy)	0.5	0.6	0.3	-42%	0.7	0.3	-52%
	Electricity Related Losses	1.1	1.2	0.7	-42%	1.4	0.7	-52%
	Total Energy	1.6	1.8	1.1	-42%	2.2	1.0	-52%
Lighting	Purchased Electricity (Delivered Energy)	1	1.1	1.1	-1%	1.2	1.2	-7%
	Electricity Related Losses	2.2	2.2	2.2	-1%	2.5	2.3	-7%
	Primary Energy	3.2	3.3	3.3	-1%	3.8	3.5	-7%
Other	Delivered Energy	4.4	5.2	5.3	3%	6.4	6.5	2%
	--Purchased Electricity	2.3	2.8	2.9	5%	3.7	3.8	4%
	--Natural Gas	1.6	1.8	1.8	0%	2.2	2.1	0%
	--Other Fuels	0.5	0.6	0.6	0%	0.6	0.6	0%
	Electricity Related Losses	4.9	5.8	6.1	5%	7.4	7.7	5%
	Total Energy	9.4	10.9	11.4	4%	13.8	14.3	3%

Table 8. Average Coefficients of Performance for Technologies Addressing Ten Energy End Uses: Reference Case vs Innovative Financing Policy

Average COP (Btu Out/Btu In)	2020		2035	
	Reference	Financing	Reference	Financing
Space Heating-Electricity	1.50	1.46	1.67	1.63
Space Heating-NG	0.79	0.87	0.82	0.91
Space Cooling-Electricity	3.18	3.22	3.40	3.45
Water Heating-Electricity	1.02	1.03	1.03	1.07
Water Heating-NG	0.84	0.85	0.86	0.88
Ventilation[1]	0.54	1.03	0.54	1.32
Cooking-Electricity	0.76	0.77	0.76	0.77
Cooking-NG	0.53	0.55	0.54	0.56
Lighting[2]	53.1	54.1	55.9	61.5
Refrigeration	2.66	2.81	2.92	3.19

1. Ventilation COP has a unit of 1000 cfm-hours output per 1000 Btu input.
2. Lighting COP has a unit of lumens/watt.

Table 9 characterizes the technology shifts based on changing service demand forecasted for six energy end-uses as the result of the innovative financing policy. The single technology with the greatest growth in service demand as the result of the innovative financing policy is the super-efficient 32-inch T8 fluorescent. This transition occurs largely from lower efficiency 32-inch T8 fluorescents to their super-efficient counterparts, amounting to a shift of more than 1 Quad of service demand. LEDs also see increasing market penetration, particularly after 2020, claiming roughly 65 TBtus of service demand met by CFL and halogen-type bulbs in the reference case.

The innovative financing policy also produces notable changes in the electric water heater market, especially heat pump and solar water heaters. In 2020 there is an uptake of heat pump water heaters relative to the Reference case; they grow by about 0.79 TBtu of service demand as a result of the 10% subsidy and the availability of a federal energy investment tax credit of 30% for heat pump water heaters purchased before the end of 2016.[2] By 2035, they have experienced a net gain in service demand of 1.26 TBtu.

The trajectory for solar water heaters is similar, as detailed in the below case study of this technology. There is only a minor uptake in solar water heaters in 2020 above the Reference case with the availability of the additional federal energy investment tax credit through 2016. Figure 10 shows that the end of the tax credit in 2016 coincides with a plateauing of the prior growth of this technology in both the Reference case and with the Financing policy beginning to

2 http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F

take effect. Throughout the period, NEMS assumes that available solar water heaters have a COP of 2.50. In 2020, GT-NEMS has a solar water heater available with a cost of $185/kBtu-out/hour in the South (including the South and West Census regions) and $267/kBtu-out/hour in the North (including the Northeast and Midwest Census regions). By 2035 solar water heaters costs have dropped to $158/kBtu-out/hour in the South and $229/kBtu-out/hour in the North.

The results for solar water heaters indicate that a 10% subsidy for this energy-efficient technology is helpful, but it does not significantly advance the technology's deployment. Currently, the US has less than 1% of the world's existing capacity of solar thermal energy (solar water heating and solar heating and cooling) (REN21, 2011, Figure 10). While a recent assessment suggests that solar water heaters produce primary energy savings of 35% over natural gas and electric resistance systems across all regions of the country (Hudon et al., 2012), current solar water heater systems cost several times more than gas and electric systems. For comparison purposes, current standard electric resistance water heaters cost $21.82/kBtu-out/hour; current standard and high-efficiency models fueled by natural gas cost $16.03 and $26.97/kBtu-out/hour, respectively. This large price differential explains the current situation where only 0.04% of US households can achieve break-even conditions on the investment. A financial subsidy of 58% would produce a break-even condition for 50% of US households (Cassard et al., 2011). Thus, it is not surprising that solar water heaters are currently a marginal player when compared to natural gas and electric resistance systems.

Recognizing the first cost hurdle faced by solar water heaters and the benefits of such technologies (fewer pollutants, increased energy security, etc.), state and federal agencies in the US have offered subsidies and financial assistance. The federal government offers a tax exemption to homeowners and businesses that install solar water heaters with the cooperation of their local electric utility. Businesses and homeowners qualify for investment tax credits of 30% of system expenditures. In addition, every state also offers financial incentives, ranging from low interest loans to tax lien financing and grants, available to both businesses and homeowners.[3] Still, these incentives are insufficient to achieve the level of cost reductions required to drive significant market penetration of solar water heaters.

Solar water heaters are seen as experiencing a more than doubling of service demand through 2020, particularly through 2016 with the 30% investment tax credit that extends into that year and the 10% subsidy applied from 2015 onward. The expiration of the tax credit results in higher prices, although these prices vary based on geographic location in the modeling (with northern systems costing more). By the out-years of the projection, solar water heaters have become an ascendant technology in the electric water heating end use, gaining 1.2 trillion Btu's of service demand in 2035 over the Energy Information Administration's *Annual Energy Outlook 2011* projection. The growth in service demand and the reduction in costs for both the North (comprised of the Northeast and Midwest Census Regions) and the South (comprised of the South and West Census Regions) – where the growth in service demand actually occurs – are shown in Figure 10.

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[3] http://www.dsireusa.org/summarytables/finee.cfm

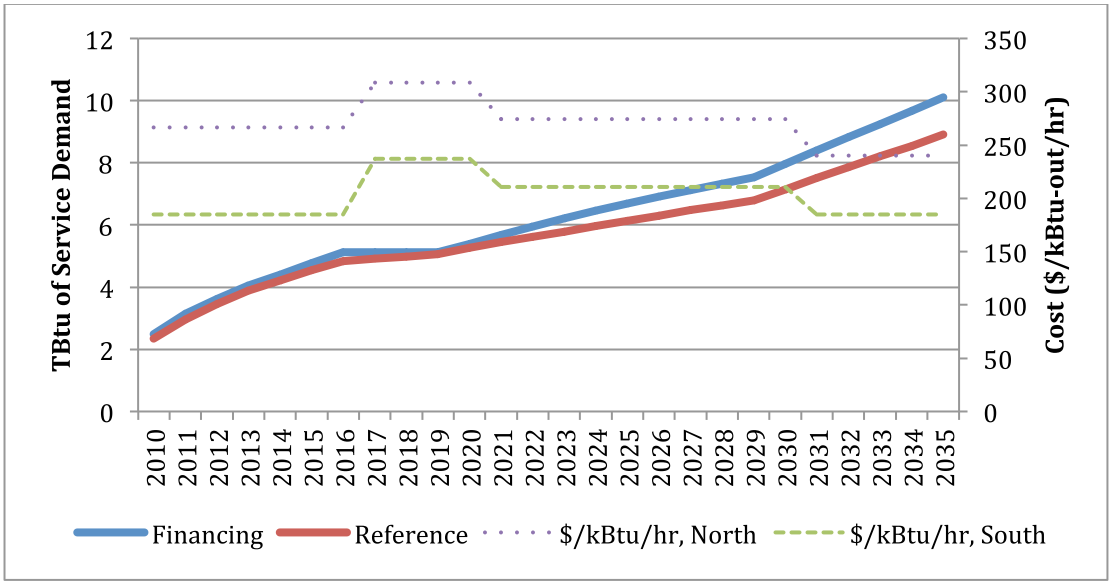


Figure 10. Service Demand Growth and Cost Reductions for Solar Water Heaters in the Commercial Buildings Sector

The financing policy is driving an increase in service demand that exceeds the Reference case by 13.5% in 2035 at more than 10 TBtus, which is roughly five times more demand than in 2010. The result is a net gain in service demand in 2035 of 1.18 TBtu for solar water heaters (comparable to the increase of 1.26 TBtu for heat pump water heaters). But these are both small increments compared with the growth in demand of 22.74 TBtu for the high-efficiency (COP 0.95) gas water heater in 2035. As a portion of service demand for water heaters generally, solar water heaters represent 0.1% of the 2.4 Quads of demand. This share quadruples to 0.4% of a 2.6 Quad demand by 2035 with the subsidy in effect. Thus, while the financing policy produces a steady growth in solar water heaters, the technology remains a marginal player in the commercial sector's water heater market overall. In conclusion, while the US is a large potential growth market, any substantial increase in deployment will require technological advances and further significant cost reductions. Although this is not modeled, further flexibility in the flexible innovative financing program could allow the program implementers to add dynamic optimization for the program since learning curves, energy costs, and other market conditions can change over time. In addition, northern cities and states may need to have a greater subsidy for solar hot water heating to price it competitively in those regions. Opportunities to tailor and adjust financing at the state and local level could yield additional energy savings.

Table 8. Technology Shifts: Innovative Financing Policy Versus Reference Case

End Use	2010-2020	2020-2035
Electric Space Heating		
– Ascendent Technologies	Ground source heat pumps with investment tax credit (COP 4.9)	Air-source heat pumps (COP 3.80); ground source heat pumps (COP 4.0)
– Declining Technologies	Ground source heat pumps with investment tax credit (COP 3.5); rooftop air source heat pumps (COP 3.3)	Rooftop air source heat pumps (COP 3.3); ground source heat pumps (COP 3.5)
Natural Gas Space Heating		
– Ascendent Technologies	High-efficiency gas furnaces (94%) and boilers (93%)	High-efficiency gas furnaces (94%) and boilers (93%)
– Declining Technologies	Low-efficiency gas furnaces (78-80%)	Low-efficiency gas furnaces (79-80%)
Electric Cooling		
– Ascendent Technologies	2007 “typical” scroll chiller (COP 2.93); mid-efficiency centrifugal chillers (COP 6.9)	2007 “typical” scroll chiller (COP 2.93); high-efficiency (3.81 COP) rooftop AC; mid-efficient centrifugal chillers (COP 6.9); high-efficiency reciprocating chiller (COP 3.63)
– Declining Technologies	Reciprocating chiller (COP 2.34); 2010 “typical” scroll chiller (COP 2.99)	Reciprocating chiller (COP 2.34); mid-efficiency scroll chiller (COP 3.08) and rooftop AC (COP 3.28)
Electric Water Heating		
– Ascendent Technologies	Mid-efficiency (COP 2.3) heat pump water heater	Mid-efficiency (COP 2.3) heat pump water heater; solar water heater (COP 2.5)
– Declining Technologies	Mid-efficiency (COP 0.98) electric water heater	Mid-efficiency (COP 0.98) electric water heater
Natural Gas Water Heating		
– Ascendent Technologies	High-efficiency (COP 0.95) gas water heater	High-efficiency (COP 0.95) gas water heater
– Declining Technologies	Low-efficiency (COP 0.78) gas water heater	Low-efficiency (COP 0.78) gas water heater
Lighting		
– Ascendent Technologies	High-efficiency F32T8 (65.2 Lumens/Watt)	High-efficiency F32T8 (65.2 Lumens/Watt); high-efficiency (181 Lumens/Watt) LED
– Declining Technologies	Low-efficiency F32T8 HE (63.6 Lumens/Watt); low-efficiency F32T8 (56.4 Lumens/Watt)	Low-efficiency F32T8 HE (63.6 Lumens/Watt); 26W CFL (41.2 Lumens/Watt)

Another important technology that is not shown in this table is high-efficiency VAV (Variable Air Volume) ventilation, which grows by 227 TBtu in 2035, largely at the expense of CAV (Constant Air Volume) ventilation. By adjusting the amount of air circulated in response to heating and cooling load requirements, VAV systems are more energy efficient than CAV systems; with a small subsidy, the market is transformed in favor of the more efficient VAV technology. These result suggest that the cost-effectiveness of offering a smaller subsidy of perhaps 5% should be explored; it may be that this technology shift could be achieved with less public support.

None of the descendant technologies highlighted in this table were subsidized. Only one of the ascendant technologies listed in this table grew in service demand despite not being subsidized: the "scroll chiller 2007 typical" with a COP of 2.93. High efficiency rooftop air conditioning also expands in service demand, as do efficient centrifugal and reciprocating chillers. The penetration of these more efficient technologies combine to produce a 7% decline in energy for electric cooling in 2035, essentially eliminating any growth in energy consumption for cooling commercial buildings during the entire 2010-2035 period.

4.7 Benefit/Cost Analysis

While the innovative financing policy option is modeled as ending in 2035, the benefits of the policy would extend into the future due to the lifetime of energy-saving technologies installed as a result of the policy. Energy-efficient technologies have varying lifetimes, with some lasting less than 20 years, and others surviving for longer periods of time (for example, natural gas water heaters do not typically last 20 years, but chillers and boilers generally last longer).[4] This analysis, consistent with the literature, assumes that energy savings degrade at 5% annually (Brown et al., 1996). Therefore, technologies installed in 2035 provide the greatest savings in that year, with a linear decline in savings out to 2055, when energy savings are no longer expected. The same rationale is applied to emissions benefits.

Table 10 presents a benefit/cost analysis of the innovative financing policy option from the private sector perspective, including energy savings and new investment costs. In total, the commercial sector would see savings of nearly 24,000 TBtus over the lifetime of the investments spurred by the financing option. Equipment expenditures increase in total, with a present value of $26.9 billion, and result in savings of more than $128 billion (2009-$), when evaluated with a 7% discount rate. From the perspective of the private sector as a whole, the financing policy offers large benefits that exceed several times over the private investment costs. As noted earlier, even with such benefits, not all stakeholders would find such results compelling enough to justify a public intervention of this scope and magnitude.

[4] See Tables 5.3.9, 5.6.9, and 5.7.15 in the DOE *Buildings Energy Data Book* http://buildingsdatabook.eren.doe.gov/).

Table 10. Innovative Financing Policy Option from the Private Sector Perspective

Year	BAU Energy Consumption	Annual Energy Savings*			Cumulative Energy Savings**		Annual Private Cost*	Cumulative Private Cost
	Trillion Btu	Trillion Btu	%	$M (2009)	Trillion Btu	$M (2009)	$M (2009)	$M (2009)
2015	18,930	270	1	2,940	270	2,940	1,444	1,444
2020	20,210	503	2	3,452	2,285	20,162	1,326	8,642
2035	23,980	1,037	4	5,328	14,275	86,830	1,117	26,935
Total Impact***	--	--	--	--	24,123	128,358	--	26,935

*Annual values are shown with no discounting to reflect the magnitude of savings in each given year. "%" refers to the percent of annual commercial energy consumption.
**Cumulative values are net present values discounted at 7%. Energy savings degrade at an annual rate of 5%, such that all policy effects have ended by 2055.
***Investments stimulated by the policy occur through 2035. "Total impact" accounts for the energy savings occurring through 2055, assuming an average equipment lifetime of 20 years.

Aside from the benefits that would pass to the private sector from reduced energy expenditures, there are additional social benefits from fewer emissions of pollutants. These are broken into criteria pollutant (SO_2, NO_x, and $PM_{2.5}$, and PM_{10}) benefits and CO_2 benefits. Changing the regulatory framework for these pollutants and other changes (lower prices or new discoveries, for example) that result in dramatic departures from projected ways of meeting energy demand would lead to different estimates of the costs and benefits associated with these pollutants.

Criteria pollutant benefits are calculated based on values from the National Research Council (2010), and take into account public health effects, damages to crops and timber, buildings, and recreation. Such damages tend to vary substantially depending on meteorological conditions, proximity of populations to emitters, and sources and means of electricity generation (Fann and Wesson, 2011). The National Research Council estimates exclude damages from mercury pollution, climate change, ecosystem impacts, and other areas where damages are difficult to monetize. Even with this incompleteness, damages from coal power plants are estimated to exceed $62 billion annually, and new analysis of this sort suggests that the damages from coal power plants exceed the value-added to the economy (Muller, Mendelsohn, and Nordhaus, 2011). The average values provided for electricity generation and on-site use of energy sources are used to analyze the emissions benefits of innovative financing.

Carbon dioxide emissions are outputs of GT-NEMS and are the result of fuels used for energy on-site and in the electricity sector. Thus, they are dynamic and change annually based on the mix of fuels used to meet commercial sector energy demand. The economic value of reductions in CO_2 is estimated by multiplying the annual decrement in emissions by the "social cost of carbon" (SCC). The SCC is an estimate of the marginal damage caused by a ton of CO_2. In this analysis, the central values of the US Government Interagency Working Group on the Social

Cost of Carbon (EPA, 2010) are used, ranging from \$25 per metric ton of CO_2 in 2015 to \$47 per metric ton of CO_2 in 2050 (in 2009-\$).

We begin the social benefit/cost analysis by examining the impacts of innovative financing on the commercial buildings sector, which is the specific target of this policy option. When compared to the Reference case, the net value of cumulative avoided CO_2 emissions is estimated at \$2.2 billion through 2020, increasing to \$123 billion by the time the last increment of benefit is assumed to occur (in 2055). The criteria pollutants have a more variable impact. In the short run, these pollutants increase and by 2020 they are responsible for \$4.3 billion in cumulative damages. These increases are due to regional changes in the electricity generation profile. By 2035, criteria pollutants would provide cumulative social benefits valued at \$7.4 billion.

Reduced energy expenditures of commercial buildings are the largest benefit, growing from \$20 billion in 2020 to \$128 billion through 2055 when evaluated with a 3% discount rate. These savings are achieved by an increased investment in energy-efficient equipment, some of which is privately funded, but the bulk of which is subsidized due to the free rider effect.

Table 11 tallies the benefits and costs of the financing policy to both the private and public sectors. Again, looking only at the commercial sector impacts, the financing policy produces net social costs through 2035, but by the end of the program's impacts, net social benefits exceed costs. Through the lifetime of the installed equipment, the energy and environmental benefits exceed costs by \$45 billion. In the early years of the policy, subsidy costs, outlays for energy-efficient equipment, and compliance costs due to the increases in criteria pollutant emissions are significant costs for the commercial sector. By 2035, cumulative energy savings, combined with the benefits of reduced emissions, are comparable (but still lower) than the cumulative equipment and subsidy costs. By 2055, all new equipment has been retired and net benefits have grown to \$45 billion. This yields a social benefit/cost ratio of 1.4 using a 3% discount rate.

Expanding the benefit/cost analysis to the national level incorporates greater savings in energy bills resulting from lower national gas and electricity rates in the residential and industrial sectors prompted by the reductions in energy use by commercial buildings. There are also comparable benefits (and costs) from associated emissions of criteria pollutants and CO_2. Altogether the cumulative social benefits grow by \$58 billion as a result of these economy-wide effects. Subsidies and administrative costs are the same, as are the outlays required to purchase more efficient technologies. Using a 3% discount rate, social benefits are equivalent to social costs in 2020, social benefits exceed costs in 2035 by \$38 billion, and by the end of the program's impacts, net social benefits are \$102 billion with a benefit/cost ratio of 1.9 when compared to the Reference case (Table 11).

As is typically the case with a benefit/cost analysis, important costs and benefits are difficult to monetize, so it is crucial to recognize this effort as a best guess (Krutilla, 1967). For example, to participate in the financing policy, consumers must incur transaction costs that include learning about the mechanics for applying for support and identify vendors who can complete the work. Such transaction costs are difficult to estimate.

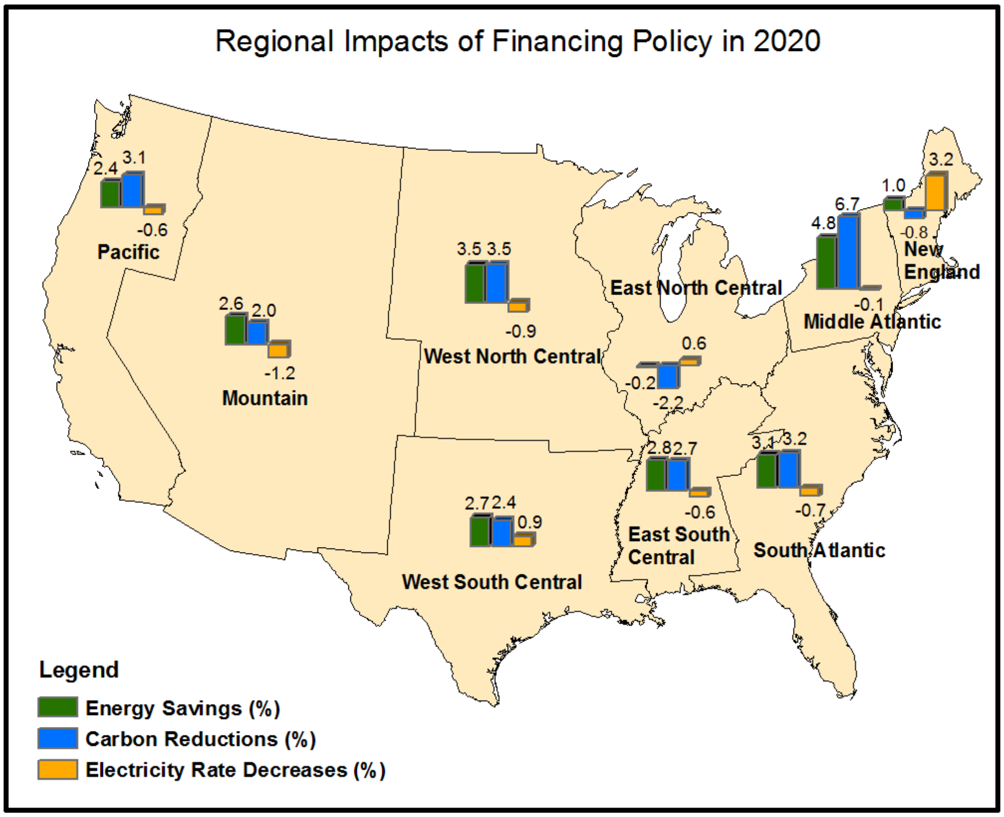
Table 11. Social Benefit/Cost Analysis of an Innovative Financing Policy*
(Billions 2009-$)

	Cumulative Social Benefits				Cumulative Social Costs				Benefit/Cost Analysis	
Year	Energy Expenditure Savings	Value of Avoided CO_2	Value of Avoided Criteria Pollutants	Total Benefits	Higher Equipment Outlays	Subsidy Costs	Administrative Costs	Total Costs	Social B/C Ratio	Net Social Benefits
				Commercial Sector						
2020	20.2	2.2	-4.3	18.0	8.6	29.2	0.4	37.8		
2035	86.8	15.1	7.4	109.3	26.9	93.4	1.5	120.3		
Total Impact**	128.4	23.1	13.5	165	26.9	93.4	1.5	120.3	1.4	45
				National Economy						
2020	37.9	0.8	-2.3	36.4	8.6	29.2	0.4	37.8		
2035	132	14.2	8.5	154.6	26.9	93.4	1.5	120.3		
Total Impact**	186.3	22.7	13.6	222.7	26.9	93.4	1.5	120.3	1.9	102

*Present values were calculated using a 3% discount rate.
***Investments stimulated by the policy occur through 2035. "Total impact" accounts for the energy savings and related benefits occurring through 2055, assuming an average equipment lifetime of 20 years.

4.8 Variations Across Regions and Building Types

The benefits of an innovative financing policy would vary geographically, based on our GT-NEMS analysis (Figure 11), even assuming similar levels of implementation in states and localities across the nation. In 2020, the East North Central division is estimated to consume more energy and emit more CO_2 as a result of the financing policy. Similarly, New England saves only 1% of its energy relative to the Reference case, and it emits 0.8% more CO_2. These regions underscore the fact that it may take time to yield positive social benefits in some regions of the country. In contrast, the other Census divisions consume significantly less energy (ranging from 2.4% in the Pacific to 4.8% in the Middle Atlantic) and would emit less CO_2 (from 2.0% in the Mountain region to 6.7% in the Middle Atlantic).



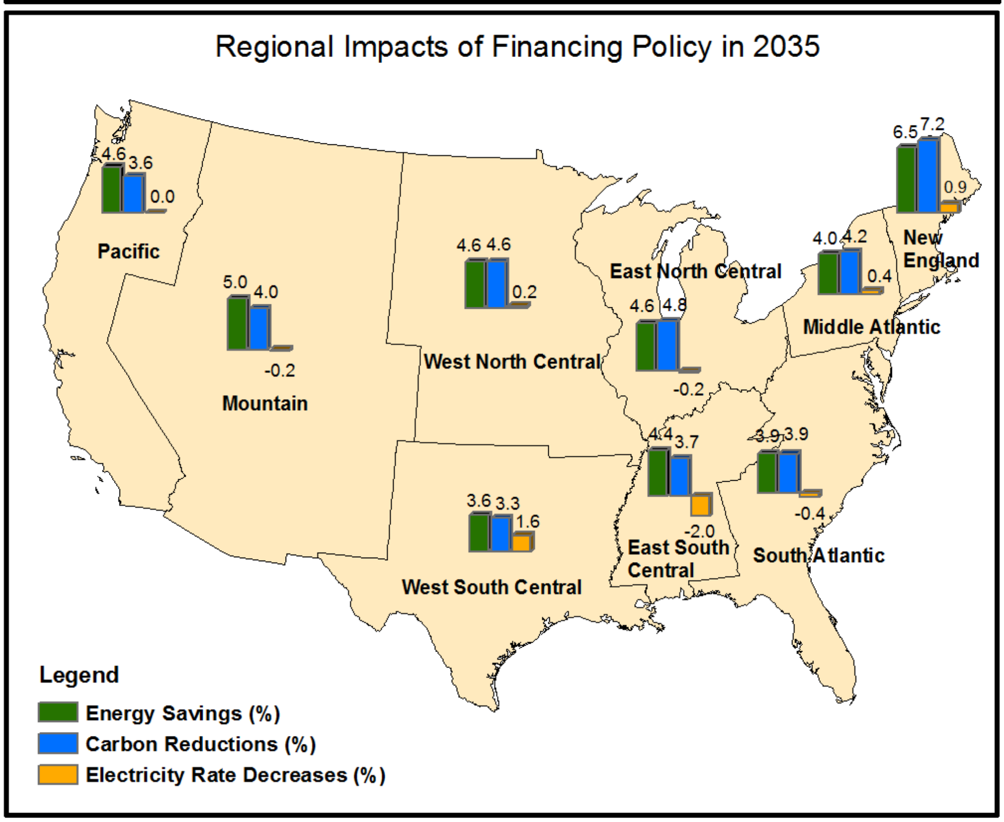


Figure 11. Change from the Reference Case in Commercial Energy Consumption, Carbon Emissions and Electricity Rates by Census Division in 2020 and 2035

The effect of the innovative financing policy in the East North Central Division is complex and unique. Demand for electricity would be reduced as a direct impact of the policy. In response, coal prices decline, as do electricity prices. Many regions see similar reductions, but the East North Central division derives the vast majority of its electricity from coal – consuming more coal than any other division in the nation. The response of this division to the national downward pressure in prices is to increase consumption. In 2020, coal in the East North Central division generates more electricity than it does in the Reference case, and CO_2 emissions rise to 2.2% above the Reference case forecast.

By 2035, all nine Census divisions are experiencing both energy and CO_2 emission reductions. The East North Central and New England divisions have become leaders in their carbon emission reductions, with savings of 4.2% and 7.2%, respectively, relative to the Reference case. Carbon emissions generally track energy consumption reductions; both increase least in the West South Central division by 2035.

As a result of less energy demand from commercial buildings, one would expect Census divisions to enjoy lower electricity rates in the commercial sector. This trend is true in only three divisions in 2020. By 2035, the financing policy is associated with lower electricity rates relative to the Reference case in most regions. The East South Central and South Atlantic divisions are notable exceptions; their significant energy and carbon savings are accompanied by electricity rate increases. In contrast, New England's rates decline (by 3.2% in 2020 and 0.9% in 2035). After expanding the generation from conventional coal-fired plants in the initial period, the region begins to retire more coal-fired plants starting from 2030 while keep the relatively more expensive oil and natural gas steam engines online. This leads to a smaller rate reduction in the division in 2035, compared to other regions.

Energy consumption continues to grow in each of the 11 building types, even with the implementation of an innovative financing policy, but the rate of growth declines significantly across the board. As shown in Figure 12, the mercantile sector is both the largest energy consumer among the different types of commercial buildings, and it also generates the largest energy savings as a result of the innovative financing policy. As is true for all of the buildings types, the percent of savings increases between 2020 and 2035, as more energy-efficient technologies are subsidized and the need to replace aging equipment expands. In mercantile buildings, energy savings increase from 6% in 2020 to 8% in 2035. Assembly buildings and health care facilities (hospitals and clinics) also have relatively high percent energy savings potential.

At the other end of the spectrum, food retailers have the smallest share of energy consumption among all commercial building types and their energy savings from the innovative financing policy is modest, at 3% in 2020 and 6% in 2035. Lodging is another type of commercial building that appears to offer relatively low percent savings from the innovative financing policy, despite being a fairly large segment in terms of overall energy consumption.

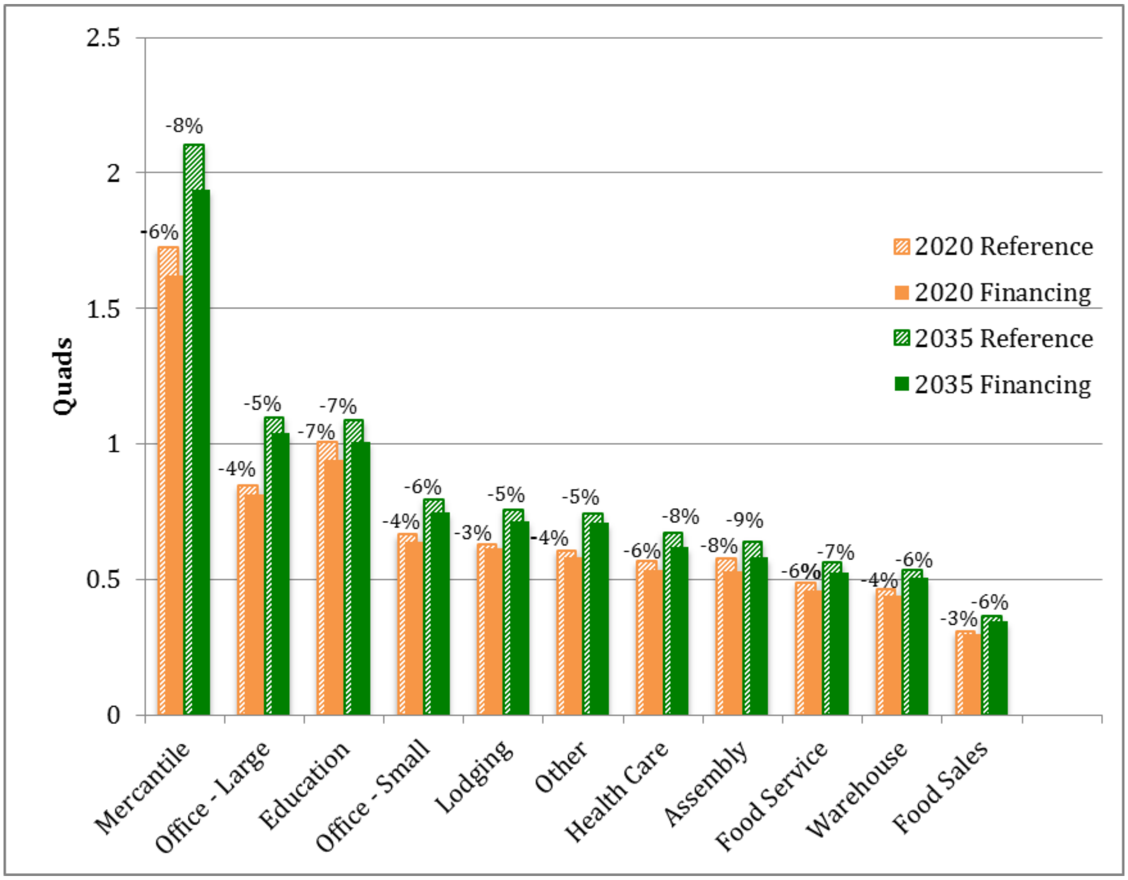


Figure 12. Energy Consumption and Energy Savings by Building Type

5. Conclusions

Investments in commercial building energy efficiency could be spurred by offering innovative financial assistance programs managed and designed by state and local agencies to meet their particular market and policy preferences and needs. An across-the-board 10% subsidy available for 64 energy-efficiency technologies would cut energy consumption by almost half a quad in 2020 and 1.04 quads in 2035 (a reduction of 2.6% of the energy consumed by commercial buildings in that year). The innovative financing program would save proportionately more electricity than natural gas.

The single technology with the greatest growth in service demand as the result of the innovative financing policy is the super-efficient 32-inch T8 fluorescent. LEDs also see increasing market penetration, particularly after 2020. The market is transformed in favor of the more efficient variable air volume ventilation systems, starting in the first five years and continuing through 2035. The innovative financing policy also produces a notable market uptake of air and ground source heat pumps. Heat pumping technologies for water heating also grow in early years, followed by gains over the next 15 years for both solar and heat pump water heaters. These are notable shifts in the electric water heating industry that occur as a result of the 10% subsidies, but both increments are small compared with the growth in demand for high-efficiency gas water heating and furnaces.

It is estimated that the benefits of a flexible innovative financing policy would outweigh the program's costs, which include the private investment and public subsidies required for installing energy-efficient equipment as well as program administrative costs. Using a 3% discount rate, the societal benefit/cost ratio for the full economy is estimated to by 1.9, with net social benefits of $105 billion. Not included in this analysis are the significant potential indoor air quality, employee health, and productivity benefits of these policies (Fisk, 2000; Kats, 2009). Opposition to such a financing policy is likely to be grounded in concerns over public debt and free ridership. Support for the policy would likely come from stakeholders who value the environmental benefits associated with a significant boost in energy efficiency. This analysis considers a full national implementation of this state and local program and advances the use of innovative policy mechanisms to achieve savings. While public budget reductions may prevent the adoption and implementation of all of these energy efficiency efforts- and the related economic and employment benefits- financing programs at this or other scales, whether individually or with complementary regulatory, information, and taxation policies, are an established means for making commercial buildings part of the climate solution.

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Appendix A. Incentivized Technologies

The Financing policy modeled in this paper provides a 10% subsidy to each of 64 energy-efficient technologies. Only 49 of these technologies are available in the Reference Case. The remaining 15 technologies are introduced in the High-Tech case, which is the basis of the technology choices in the Financing case. These 15 technologies are shown in red in the following table of the 64 incentivized technologies.

Table A-1. List of 64 Incentivized Technologies

Space Heating (9)	**Ventilation (2)**
comm_GSHP-heat 2011 high	CAV_Vent 2008 high
comm_GSHP-heat 2011 high 10% ITC w MACRS	VAV_Vent 2008 high
comm_GSHP-heat 2020-30 typical	**Cooking (2)**
gas_boiler 2011 high	Range, Electric-induction, 4 burner, oven, 11" gri
gas_furnace 2011 high	Range, Gas, 4 powered burners, convect. oven, 11"
res_type_gas HP-heat 2020 typical	**Lighting (4)**
res_type_gas HP-heat 2030 typical	F32T8 Super
rooftop_ASHP-heat 2007 high	F96T8 High
rooftop_ASHP-heat 2030 high	LED 2011-2019 Typical for high tech
Space Cooling (17)	LED 2020-2029 Typical
centrifugal_chiller 2007 high	**Refrigeration (23)**
centrifugal_chiller 2007 mid range	Bevrg_Mchndsr 2008 high
comm_GSHP-cool 2011 high	Bevrg_Mchndsr 2020 typical
comm_GSHP-cool 2011 high 10% ITC w MACRS	Bevrg_Mchndsr 2030 typical
comm_GSHP-cool 2020-30 typical	Ice_machine 2010 EPACT standard
reciprocating_chiller 2007 high	Ice_machine 2011-2020 typical
reciprocating_chiller 2020 high	Reach-in_fzr 2008 high
reciprocating_chiller 2030 high	Reach-in_fzr 2030 typical
res_type_central_AC 2030 typical	Reach-in_refrig 2008/2010 high
rooftop_AC 2010 high	Supermkt_compressor_rack 2011 high
rooftop_AC 2030 high	Supermkt_compressor_rack 2020 high
rooftop_ASHP-cool 2030 high	Supermkt_compressor_rack 2030 high
screw_chiller 2020 high	Supermkt_condenser 2008 high
screw_chiller 2030 high	Supermkt_display_case 2008 high-2012 standard
wall-window_room_AC 2007 E-star	Supermkt_display_case 2020 high
wall-window_room_AC 2007-10 high	Vend_Machine 2011 high
wall-window_room_AC 2011 high	Vend_Machine 2020 high
Water Heating (7)	Vend_Machine 2030 high

gas_water_heater 2020 high	Walk-In_fzr 2009 EISA stnd-2010 typical
HP water heater 2011 typical	Walk-In_fzr 2020 typical
HP water heater 2020 typical	Walk-In_fzr 2030 typical
Solar water heater 2010 typ south	Walk-In_refrig 2008 high
Solar water heater 2011 typ 30 pct ITC south	Walk-In_refrig 2020 typical
Solar water heater 2020 typ south	Walk-In_refrig 2030 typical
Solar water heater 2030 typ south	

Appendix B. Sample Spreadsheet Analysis of Input Assumptions

The following results characterize the net present value calculations for a financial policy that promotes replacing one incandescent bulb with one LED lamp.

An Exercise in Replacing One Light Bulb through Financing:

- 40 Watt equivalent LED
- Costs $25.88 (10% bulk discount to $23.29)
- Assumed 5% discount rate.

Figure B-1 shows how we calculated the net present value for a sample financing policy. It is worth noting that while Fuller, Portis, and Kammen (2009) use an interest rate of 7% over 20 years to show that Berkeley FIRST can have a significant factor on the residential sector, experience shows that interest rates in the commercial sector for energy efficiency through public intervention can fall to as low as 4% (Sciortino, 2011).

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

- B= Benefits (savings); C= Cost (of upgrade); t= year; n= numbers of years; r= discount rate
- All cost repayment occurs over time in equal amounts over the life (n) of the program.
- Costs includes annual interest repayments.
- Annual costs get adjusted for program impacts (reduced interest rate, subsidies, bulk discounts, etc.)

Figure B-1. Net Present Value Calculation

Present values of energy savings:

- 15 years: $59.79
- 10 years: $44.48
- 5 years: $24.94
- 3 years: $15.96

Benefit Cost (B/C) ratio is 2.57 (15 years); B/C ratio is 2.85 at 10% cost reduction:

- A 2% buy-down on the interest rate reduces annual repayment on a 15 year program reduces annual repayment from $2.24 per year to $1.95 per year.
- Repayment is well below energy savings value in all scenarios. The new lighting can pay for itself for the commercial facility within five years.

By program type:

- Loan Loss Reserve: 22% present value cost savings of the lighting to the customer due to bulk purchasing and reduced interest rates.
- Revolving Loan Fund: 13% reduction in annual repayments for program participants.

- PACE Financing: $1.95 in additional annual tax burden for 15 years for repayment of upfront program costs.
- Energy Savings Performance Contracting: Up to $23.29 in benefits split between the ESCO and consumer based on contract stipulations.
- On-Bill Financing: Savings are greater than annual repayments, resulting in consumer paying lower electricity bills despite investment.
- Synergies can reduce costs further.

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Appendix C
Calculation of Capital Investment Costs

GT-NEMS does not directly calculate the capital investment costs to upgrade the end-use equipment including space heating and cooling, water heating and lighting equipment. Nevertheless, it provides the unit cost, coefficient of performance, and capacity factor for each commercial technology and the service demand it fulfills. Based on this information, we developed a spreadsheet analysis tool that calculates the capital investment cost for every end-use technology vintage in the commercial sector and use it to analyze the equipment investment costs under both the Reference and innovative financing scenarios. These estimates of investment costs are derived from the outputs of the GT-NEMS Reference case, High-Tech Case, and Financing policy scenario (specifically, the KSDOUT, KTEK, and KCAPFAC files).

In estimating the investment costs, we treat new purchased equipment, replacements, and retrofits separately for major end-uses including space heating, space cooling, water heating, refrigeration, cooking, and lighting. Due to questionable results for ventilation, we estimate equipment costs for that end-use by using the ratio of equipment costs to electricity savings from space cooling. In addition, for heat pumps that are used to meet both space heating and cooling demand, we account for only the cost occurred in the space heating end use to avoid double-counting.

Details of the calculation method are illustrated in the following three equations. In general, the investment costs are calculated using service demand of each technology vintage multiplied by the corresponding capital cost and then adjusted for the capacity factor. NEMS provides specific service demand data for new purchases and replacements that can be used directly in the calculation. An additional assumption of 2.2% annual average retrofitting rate for commercial floorspace is used to calculate the service demand from commercial buildings that undergo retrofits.

- Investment Cost of New Purchases = SD_{new} x (Cost/8760) x 1/CF
  - SD_{new} denotes the service demand met by equipment purchased for newly constructed floorspace. It is a technology-specific KSDOUT output, as are $SD_{replacement}$ and $SD_{surviving}$
  - Cost is a technology specific variable from KTEK. It represents the annualized capital cost for every thousand Btu of service demand.
  - 8760 is the number of hours in a year
  - CF refers to the capacity factor corresponding to each technology. It is an input from KCAPFAC.
- Investment Cost of Replacements = $SD_{replacement}$ x (Cost/8760) x 1/CF
  - $S_{Dreplacement}$ denotes the service demand met by equipment purchased for existing commercial floorspace to replace those that reached the end of their lifetime.
  - CF refers to the capacity factor corresponding to each technology. It is an input from KCAPFAC.
- Investment Cost of Retrofits = $SD_{surviving}$ x (Cost/8760) x 1/CF x 0.022/($SD_{surviving}$/SD_{total})
  - $SD_{surviving}$ denotes the service demand met by equipment that still have economical lifetime left and is continuously used in existing commercial floorspace.

- The relationship of the service demand variables follows $SD_{total} = SD_{new} + SD_{replacement} + SD_{surviving}$
- 0.022 is the average annual retrofitting rate in the commercial building sector. This proportions the surviving service demand to the commercial sector retrofit average

Our method only covers seven major end-uses in commercial buildings, which account for about 60% of today's energy consumption in commercial buildings. The incremental investment cost for minor end-uses are believed to be minimal because the Financing policy examined in this study does not directly target these technologies. Although the reduced energy prices resulting from the Financing policy could also potentially affect the technology choice in the minor end-use categories (office equipment PCs, office equipment non-PCs, and other), GT-NEMS does not include a technology menu, instead assuming an annual efficiency improvement rate for each category. With no explicit cost and service demand estimate for each technology, we are not able to apply the method described above to calculate the investment costs for the minor end-uses. Nevertheless, a study conducted by Lawrence Berkeley National Lab (Koomey, Piette, Cramer, and Eto, 1996) found that for most of the office equipment, the cost difference between high and low energy-efficient equipment is small, indicating a negligible efficiency upgrade cost.

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