POTENTIAL FOR ENERGY EFFICIENCY, DEMAND RESPONSE, AND ONSITE SOLAR ENERGY IN PENNSYLVANIA

April 2009

American Council for an Energy-Efficient Economy,
Summit Blue Consulting, Vermont Energy Investment Corporation,
ICF International, and Synapse Energy Economics

ACEEE Report Number E093

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Disclaimer: While several organizations, including Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International, and Synapse Energy Economics, assisted ACEEE in the completion of this analysis and report, the ultimate viewpoints and recommendations expressed herein are those of ACEEE.

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ACKNOWLEDGMENTS

This report was funded by the Pennsylvania Department of Environmental Protection, the U.S. Department of Energy, and the U.S. Environmental Protection Agency. The authors would like to thank the many people in Pennsylvania who contributed data, suggested contacts, or participated in discussions or interviews, including: Liz Robinson (Energy Coordinating Agency of Philadelphia); Dan Griffiths and Dennis Maloskey (PA DEP); Maureen Mulligan (solar industry); Roger Clark (TRF Fund); Linda Wigington, Helen Perrine, and Gloria S. Fultz (Affordable Comfort); Wayne Williams, Calvin Birge, John Miller, David Mick, and William Hall (Pennsylvania PUC); Lisa Crutchfield, Kurt Sontag, Kathy Lentini, Paul Miles, Rich Schlesinger, and Frank Jiruska (PECO Energy); and Michael Turns (Pennsylvania Housing Research Center–PHRC). Several additional contributors provided feedback on a draft of the report: Harvey Sachs (ACEEE); David Shiller (MAXLITE); Ron Celentano (Mid-Atlantic Solar Energy Industries Assoc.–MSEIA); David Althoff and Dennis Maloskey (PA DEP); Kevin Warren (Warren Energy Engineering); Ben Adams (MaGrann Associates); John Haak (Philadelphia City Planning Commission); Chris Ross (Pennsylvania House of Representatives); and Mark Fortney and Michael Turns (PHRC). Finally, thank you to our technical editor, Renee Nida, for her final edit and production of the report.

ABOUT THE AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY (ACEEE)

ACEEE is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. For more information, see http://www.aceee.org. ACEEE fulfills its mission by:

- Conducting in-depth technical and policy assessments
- Advising policymakers and program managers
- Working collaboratively with businesses, public interest groups, and other organizations
- Organizing conferences and workshops
- Publishing books, conference proceedings, and reports
- Educating consumers and businesses

Projects are carried out by staff and selected energy efficiency experts from universities, national laboratories, and the private sector. Collaboration is critical to ACEEE's success. We collaborate on projects and initiatives with dozens of organizations including federal and state agencies, utilities, research institutions, businesses, and public interest groups.

Support for our work comes from a broad range of foundations, governmental organizations, research institutes, utilities, and corporations.

EXECUTIVE SUMMARY

The Commonwealth of Pennsylvania is poised to catapult forward its commitments to clean energy resources. Facing a severe economic crisis, rising energy prices, and growing energy demand, Pennsylvania is looking for solutions to both strengthen the economy and to shape a cleaner and more reliable energy future. Enabled by both a pressing need for economic development and President Obama's stimulus plan for clean energy investments, the Commonwealth is in a position to significantly increase its clean energy infrastructure. Such investments, including energy efficiency and solar resources, offer a three-fold benefit to an ailing economy: (1) new, "green collar" jobs to ease unemployment; (2) lower consumer energy bills to alleviate rising energy prices for strained household budgets; and (3) increased energy reliability to ensure that Pennsylvania's energy infrastructure can support the state's future needs. Given the substantial potential for energy efficiency and solar energy, a sustained commitment to clean energy resources can generate these economic benefits to the Commonwealth.

In 2008, Pennsylvania passed two major pieces of legislation: The Alternative Energy Investment Fund, which established a clean energy fund of 650 million dollars to provide incentives for energy efficiency and clean energy resources; and Act 129, which imposed new energy efficiency requirements on electric distribution companies (EDCs), with the overall goal of reducing energy consumption and peak demand. These steps represent major milestones for the Commonwealth; however, much more potential for energy efficiency remains and many more economic and jobs benefits stand to be gained by tapping energy efficiency as a resource. And with concerns mounting over the pending expiration of electricity rate caps and predicted rate hikes, energy efficiency offers the only resource consumers can use to actually *reduce* energy bills and soften the impact of rising prices. Finally, aggressive, statewide energy efficiency strategies have the added benefit of improving the balance of supply and demand in energy markets, thereby stabilizing regional electricity prices for the future. For these reasons, energy efficiency must be deployed as the "first fuel" to help Pennsylvania energy customers and the overall economy.

Characterizing the Energy Efficiency Resource Potential

In this report, we first assess the total cost-effective, or "economic," potential for energy efficiency in Pennsylvania. By characterizing the incremental costs and energy savings for a number of efficient technologies or measures for residential, commercial, and industrial consumers, we determine the cost-effectiveness for each measure and estimate the total energy efficiency "resource" potential. Based on the findings of this analysis, we estimate that about 30% of Pennsylvania's projected electricity, natural gas, fuel oil, and propane needs can be met through existing, cost-effective efficiency measures that are widely available today. We estimate that there is an economic potential for energy efficiency in 2025 to meet about 61,000 GWh, or 33%, of Pennsylvania's electricity use; 174,000 BBtu, or 27%, of natural gas needs; and 320 million gallons of fuel oil, or 29% of the state's projected needs. As shown in Figure ES-1, each customer sector has the potential to contribute various portions of the total efficiency resource depending on the energy form examined. And through new, emerging technologies that are not characterized in this analysis, the potential for energy efficiency will continue to grow by 2025.

Policy Suggestions and Impacts

Next, the report outlines and assesses a specific suite of energy efficiency, demand response, and onsite solar policies and programs that have the potential to meet a significant share of the state's energy needs in 2025. As shown in Figure ES-2, the growing demand for electricity in the Commonwealth can be met through energy efficiency and onsite solar, so that by 2025 these demand-side resources can meet about a quarter of the state's electricity need. Likewise, there is significant potential through actionable policies for energy efficiency for natural gas, fuel oil, and propane customers. The suggested suite of policies, which are summarized in Table ES-1, also can reduce carbon dioxide by 40 million tons, save consumers $4.8 billion dollars annually, and create a net 27,000 jobs by 2025.

Figure ES-1. Share of Cost-Effective Energy Efficiency Resource Potential by Sector in 2025

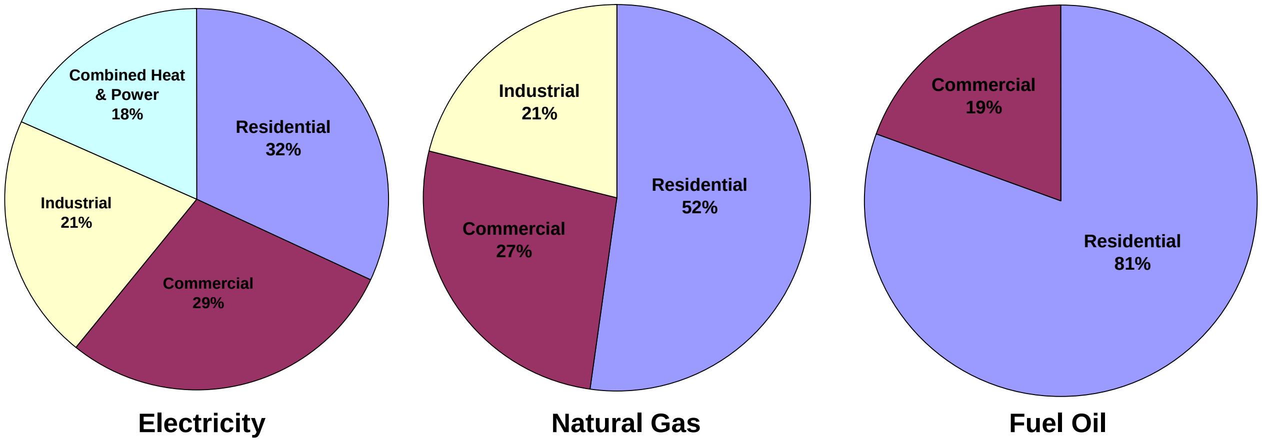
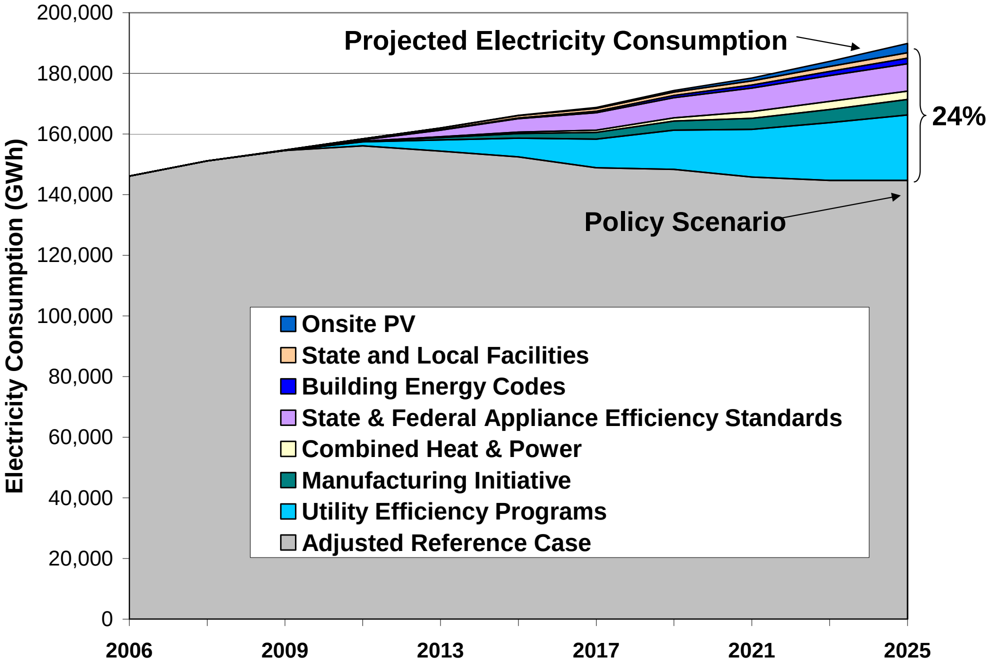


Figure ES-2. Policy Impacts: Share of Projected Electricity Use Met by Energy Efficiency



Addressing Peak Demand

Peak demand, which occurs in Pennsylvania in the summer during those times of highest electricity use, incurs significant costs to consumers. Pennsylvania can reduce peak demand through "permanent" demand reductions from energy efficiency and also demand response programs that have the capability to shift demand to off-peak hours when needed. Our analysis suggests that up to 14% of Pennsylvania's projected peak demand in 2025 can be met through demand response efforts. And combined, energy efficiency and demand response have the potential to reduce peak demand by 35% by 2025 compared to the forecast (see Figure ES-3).

Table ES-1. Summary of Suggested Energy Efficiency Policy Suite for Pennsylvania

Appliance and Equipment Efficiency Standards. Push for strong federal efficiency standards and encourage additional state-level opportunities for appliance efficiency standards.

Building Energy Codes and Enforcement. Support stringent codes for new buildings at least on par with recommendations made at the federal level: 30% beyond IECC by 2012; and 50% beyond IECC by 2020. Expand code official and builder training efforts to increase code enforcement and launch regular assessments of code compliance.

Energy Efficiency Resource Standard (EERS) for Electricity and Natural Gas Distributors. Extend and increase electricity savings targets in Act 129 to reach 1.25% incremental annual savings per year by 2015, 1.5% by 2017, and 1.75% by 2022. Also, establish EERS targets for natural gas distributors of 0.25% per year and ramping up to 1% per year by 2018. Support an industrial initiative to enable energy savings in the industrial sector and promote increased penetration of CHP systems to help meet EERS targets. Finally, review enabling policies to encourage utilities to go beyond the required energy efficiency targets, such as creation of a “loading order” that requires utilities to first procure all cost-effective energy efficiency resources before procuring other resources.

Industrial Initiative. Establish a government/utility/industrial collaborative to address the three key barriers to expanded industrial energy efficiency: the need for assessments that identify energy efficiency opportunities; access to industry-specific expertise; and the need for an expansion of the trained manufacturing workforce with energy efficiency experience. The initiative could start by expanding efforts at the current Industrial Assessment Center (IAC) at Lehigh University, and eventually opening another center in western Pennsylvania. Expanding beyond the IAC model, these centers would partner with local community colleges and trade schools to bring their students into the larger network centered on the local Center of Excellence.

Combined Heat & Power: Financial Incentives and Regulatory Policies. Leverage federal tax credits for Combined Heat & Power (CHP) with state financial incentives to incentivize customer installation of CHP systems. Support CHP as eligible for state EERS targets; establish output-based emissions regulations; and review standby tariffs for CHP systems.

Demand Response. Expand demand response (DR) capabilities by: (1) integrating and cross-marketing energy efficiency and demand response programs; (2) considering residential and small business air-conditioning direct load control programs; (3) educating customers on demand response offerings and benefits; (4) increasing clarity and coordination between federal and state agencies and programs; and (5) expanding customer participation in time-of-use (TOU) pricing and day-ahead hourly pricing to increase overall market efficiency.

Onsite Solar Strategies. Continue a sustained effort to provide financial incentives and offer financing to reduce high upfront solar system costs. Ensure equipment availability through active recruitment and incentives for manufacturers of solar panels and system components throughout PA and by linking economic development and renewable energy public policy goals. Support quality installation infrastructure through workforce development, installer job training and certification, and quality assurance programs. Develop program capabilities and capacity to keep up with application flow and inspections.

Consumer Financial Incentives. Expand existing energy efficiency financial incentive programs for residential consumers and small businesses, now offered by the Pennsylvania Department of Environmental Protection (DEP), which include a loan program in conjunction with the Keystone HELP loan program and a customer rebate program. As prospective long-term EERS targets for electric and natural gas utilities would encourage efficiency for electric and gas customers, gear this consumer financial program toward fuel oil and propane users.

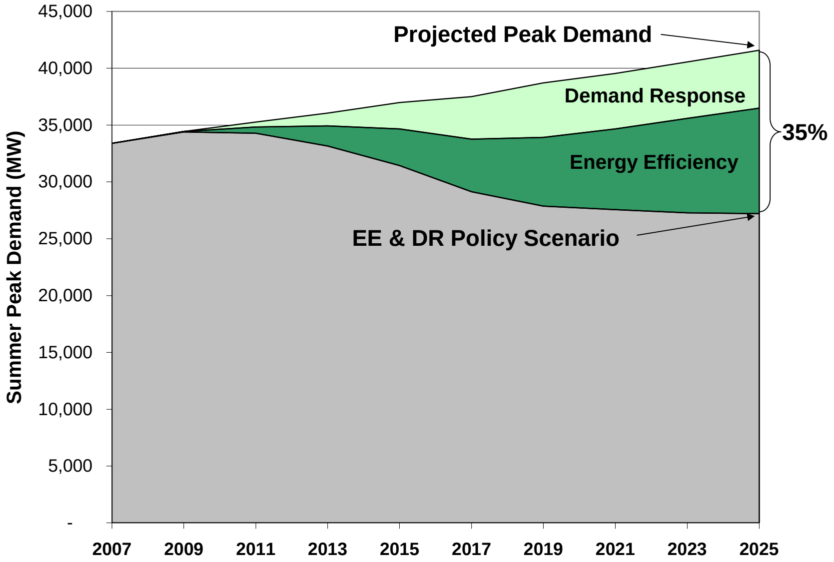
State and Local Facilities: Energy Service Performance Contracting (ESPC). Pennsylvania’s existing ESPC in state facilities program is one of the leading efforts of its kind in the country. Continue to ramp up the state facilities program and extend the model to local government to reach 100% of facilities with energy efficiency services by 2025. Continue to identify streamlined processes and modifications to existing programs to best achieve energy services for public facilities.

Low-Income Energy Efficiency Programs. Expand and increase the effectiveness of low-income energy efficiency services through the Weatherization Assistance Program (WAP) and electric and natural gas companies’ Low Income Usage Reduction Program (LIURP). Establish strong coordination among LIURP, WAP, and DEP financial incentives programs in order to best serve low- and moderate-income households.

Workforce Development. Establish an interagency stakeholder group to coordinate workforce development activities, bringing together entities such as the PUC, the Department of Community and Economic Development (DCED), DEP, Labor and Industry, the Pennsylvania Economic Development Association (PEDA), and municipal organizations.

Public Education Campaign. To kick-start near-term initiatives, such as energy efficiency financial programs offered by DEP and federal stimulus efficiency initiatives, establish a statewide public education campaign to increase consumer awareness.

Figure ES-3. Peak Demand Impacts from Energy Efficiency and Demand Response



Onsite Solar Assessment

Solar energy is an abundant resource in Pennsylvania. An analysis of the technical potential for onsite solar electricity using photovoltaics (PV), solar water heating (SWH), and solar air heating (SAH) shows that solar resources can offset about 29,000 GWh and 66 TBtu of conventional electric generation and fossil fuels statewide, equivalent to 20% of all residential energy use and 39% of all commercial energy use. The market potential analysis, which provides indicators of expected market growth based on current initiatives and market strategies, estimates that nearly 100,000 PV systems could be installed by 2020 contributing 680 MW of solar capacity.

Recently, the governor, legislature, and state regulatory bodies in Pennsylvania established several initiatives that serve as early catalysts for enabling onsite solar energy use in the state, including the existing Alternative Energy Portfolio Standard, Alternative Energy Investment Fund, net metering regulations, and Standardized Interconnection Rules. Also benefiting from the federal stimulus plan for state clean energy investments, the Commonwealth stands to make important strides in tapping its solar energy resource in the coming years. However, continued thought, care, and action will be needed to ensure the state meets existing (or anticipated) solar targets rapidly and cost-effectively. Looking forward, programs, policies, and investments will need to be tailored toward reducing and removing the market barriers to greater solar market development, such as sustained incentives and financing, ensuring equipment availability, and development of a quality installation infrastructure through workforce development, installer job training and certification, and quality assurance and inspections programs.

Economic and Job Impacts

The current economic crisis, which is affecting states around the country, has resulted in layoffs by the thousands. In 2008, Pennsylvania lost about 76,000 jobs, and the state faces at least a $2 billion state budget shortfall, portending the need for more layoffs. ACEEE estimates that sustained investments in energy efficiency, encouraged through our suggested suite of programs and policies, can have a net positive effect on employment in Pennsylvania. As shown in Table ES-2, our analysis shows that energy efficiency will create 27,000 new jobs in the Commonwealth, including well-paying trade and professional jobs needed to install energy efficiency and solar measures. These new jobs, including both direct and indirect employment effects, would be the equivalent of some 200 new manufacturing plants relocating to Pennsylvania.

Table ES-2. Jobs, Wages, and GSP Impacts from Energy Efficiency and Onsite Solar in Pennsylvania

Macroeconomic Impacts	2020	2025
Net Jobs (Actual)	14,500	27,200
Wages (Million 2006$)	$440	$1,100
GSP (Million 2006$)	$1,020	$2,600

In addition to stimulating new job growth, the energy savings from these energy efficiency policies also have the potential to cut the energy bills of customers implementing efficiency measures by a net, annual $2.7 billion in 2020 and $4.8 billion in 2025. Both public and customer investments will spur these energy bill savings, and will yield a return of $2 to $3 in reduced consumer energy bills for every dollar invested. In addition, because of the current volatility in energy prices, efficiency strategies have the added benefit of improving the balance of demand supply in energy markets, thereby stabilizing regional electricity prices for the future.

The energy efficiency policy suite also has the potential to save about 40 million tons of carbon dioxide by 2025, creating a sizeable down payment on greenhouse gas (GHG) emissions reductions. And Pennsylvania can lower the future costs to address global warming by reducing emissions through low-cost energy efficiency measures, which can buy-down the cost of other investments to meet future GHG reduction requirements.

Philadelphia and Pittsburgh Metropolitan Areas

Together, the metropolitan areas encompassing Philadelphia and Pittsburgh comprise about 50% of the state in terms of population and energy consumption.[1] Considering this high concentration of energy use, strategically targeting these urban and suburban areas will help Pennsylvania to kick-start its energy efficiency efforts. In addition to directing statewide efforts to these regions, there are specific steps that the metro regions can take to amp up its energy savings opportunities. Building energy codes, for example, are established at the state level but enforced at the local level. Local efforts and partnerships with statewide efforts to train building code officials and builders can stimulate greater effectiveness of building codes and can mobilize the existing workforce. Energy efficiency programs geared toward multifamily buildings, which have not been run for years, will also be an important strategy for these metro regions.

Conclusions

Pennsylvania took significant steps in 2008 toward a cleaner and more reliable energy future. And the opportunities that lie ahead offer even greater solutions to the Commonwealth's ailing economy, rising energy prices, and strained household budgets. Based on the energy efficiency, demand response, and onsite solar analyses included in this report, Pennsylvania has the opportunity to meet a significant share of its growing energy needs through demand-side resources, while greatly benefiting its economy and environment. These strategies will reduce consumer energy bills by billions of dollars, create tens of thousands of new, in-state jobs, and shape a cleaner and more reliable energy future.

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[1] The metro regions are defined by the several Pennsylvania counties that comprise the Census Bureau's Metropolitan Statistical Areas (MSA) of Philadelphia and Pittsburgh.

INTRODUCTION

Since 2000, electricity consumption in the Commonwealth of Pennsylvania has risen at nearly 2% per year and usage is expected to continue to rise steadily at about 1.4% per year between 2008 and 2025. Peak demand, or use of electricity during the hottest days of each year, is also expected to grow. This growing need for energy is compounded by the fact that energy markets have become increasingly volatile and electricity rate caps for most Pennsylvania customers are coming off in the next 2 years, creating concerns about high consumer energy bills that will increasingly strain household budgets. Consumer energy bills for natural gas and fuel have faced alarming volatility that also strains household budgets. As this report will demonstrate, there is significant potential for clean energy solutions, including energy efficiency, demand response, and onsite solar technology, to revitalize the economic health of Pennsylvania while simultaneously moderating the impacts of increasing energy needs and volatile energy markets.

Energy efficiency is the least-cost resource available to meet energy needs in Pennsylvania, is the quickest to deploy for near-term impacts, and has a positive net benefit on job creation and economic stimulus. With electricity rate caps expiring for most electricity customers in the state by 2010, some utilities are projecting rate increases.[2] Unlike supply-side energy resources, energy efficiency and demand response are the only resources that can actually begin to *reduce* customer electric bills by reducing overall consumption. And by freeing up dollars in consumer budgets, these clean energy investments can stimulate the economy and create new “green collar” jobs in fields such as construction and technology development and deployment.

Recent legislation in Pennsylvania that aims to encourage energy efficiency and renewable energy investments (the Alternative Energy Investment Fund and Act 129) and a growing awareness of the value of these resources demonstrate a growing consensus that the Commonwealth must do more to realize these clean energy resources. The goal of this study is to inform policymakers, stakeholders, and the general public of the opportunities for energy efficiency, demand response, and onsite solar energy in Pennsylvania, and to suggest specific policy and program recommendations the Commonwealth could implement to tap into these clean energy resources.

The report is organized into the following sections:

- **Background:** Provides a brief overview of the electricity, natural gas, and fuel oil markets in Pennsylvania, including recent actions and future opportunities regarding energy efficiency and demand response.

- **Project Overview and Methodology:** Provides a context for ACEEE’s work with state-level energy efficiency potential studies and an overview of both the project approach and analysis methodology.

- **Reference Case:** Discusses the reference case electricity, peak demand, natural gas, fuel oil, propane, and price forecasts used in this analysis.

- **Energy Efficiency Resource Assessment:** Estimates the cost-effective potential, from the customer’s perspective, for increased energy efficiency in the state’s residential, commercial, and industrial sectors by 2025 through the adoption of specific energy-efficient technology measures. The resource assessment goes beyond what the state can achieve through penetration of specific programs and policies.

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[2] PPL Electric Utilities Corporation has advised its customers to expect at least a 25% increase when rate caps come off (PPL 2007). However, electric rates for PennPower and Duquesne residential and commercial customers have decreased (in real dollars) about 30% over the past 15 years and PECO is projecting residential rate increases of 8 percent (DEP 2009).

- **Onsite Solar Assessment:** Characterizes the technical and market potential for onsite PV and solar water and space heating. Prepared by the Vermont Energy Investment Corporation (VEIC).
- **Energy Efficiency Policy Analysis:** Outlines the recommended policies for Pennsylvania to adopt to tap into the energy efficiency resource potential and estimates the energy savings impacts from energy efficiency policies.
- **Demand Response Analysis:** Estimates the potential for increased demand response in Pennsylvania and makes specific recommendations to the Commonwealth.
- **Macroeconomic Impacts:** Estimates both the costs and consumer energy bill savings from the policy analysis, and assesses the impact of energy efficiency policies on Pennsylvania's economy, employment, and energy prices.

BACKGROUND

The Commonwealth of Pennsylvania consumes over 4 quads of total energy per year and ranks 7th in the U.S. in total energy consumption, but 6th in population. This report focuses on end-user energy efficiency opportunities for the state's residential, commercial, and industrial consumers, which cover 25%, 18%, and 32% of total energy consumption in the state, respectively. The transportation sector, which makes up the remaining 25%, is not covered in this analysis (for a discussion of state-level opportunities for increased efficiency in the transportation sector, see Geller et al. 2007). In this section we discuss the current condition of the Pennsylvania electricity market, natural gas, and fuel oil and propane consumption in the state, and the overall role of energy efficiency and related opportunities to meet the state's energy needs.

Electricity Market

In December 1996, Pennsylvania enacted the Electricity Generation Customer Choice and Competition Act (Customer Choice Act) to restructure the electric industry in the Commonwealth. As Pennsylvania's electric utilities submitted restructuring plans to the Pennsylvania Public Utility Commission (PUC), some utilities established sustainable energy funds as part of their settlement process, though funding for energy efficiency and programs for the most part vanished post-restructuring.

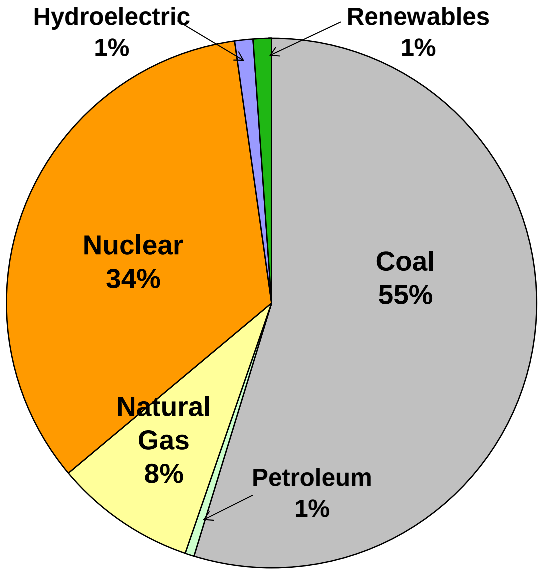
Electricity rate caps, which were put into place following restructuring, have come off in six utility service territories that supply electricity to about 15% of utility customers. The rate cap for PPL Electric Utilities Corporation, which supplies electricity to about 25% of customers, will expire on December 31, 2009, and the caps for the remaining utility companies, which supply energy to the other 65% of customers, are set to be removed by December 31, 2010 (PUC 2008a). PPL Electric Utilities Corporation has advised its customers to expect at least a 25% increase when rate caps come off (PPL 2007). Governor Rendell is encouraging the state legislature to use a phased structure for implementing the rate increase and has suggested extension of the rate caps for several years if the legislature does not act. In areas where the rate caps have already expired Pennsylvania's electric customers have seen their bills increase 20-30% (except in the Duquesne service area where rates decreased), and over the next few years when the rest of the caps expire electricity bills could increase by as much as 50%.

The amount of electricity generated in Pennsylvania (see Figure 1) is greater than the electricity needs of consumers, meaning that the state is a net exporter of electricity. Because Pennsylvania's major electric utilities are interconnected with neighboring systems extending beyond state boundaries, electricity generated in-state is sold throughout the region. The manager of the wholesale power market in the region is PJM Interconnection, the regional transmission organization (RTO) which coordinates the operation of more than 160,000 MW of generating capacity and the movement of electricity throughout thirteen states, including Pennsylvania (except for one small portion of western Pennsylvania that is in the Midwest ISO).[3]

In addition to managing the wholesale power market, PJM also provides reliability planning and manages long-term regional electric transmission planning. In 2006, PJM approved a five-year regional transmission expansion plan designed to maintain reliability of the electric transmission grid, including three major transmission line projects that would have a significant impact on Pennsylvania (PUC 2008b). Although there is expected to be sufficient generation, transmission and distribution capacity to meet the needs of Pennsylvania electricity customers in the near future, there are generation adequacy concerns beginning in 2013 (PUC 2008b).

Figure 1. 2007 Electricity Generation in Pennsylvania

Total Generation = 227,278 GWh



Source: EIA 2008a

Natural Gas

Natural gas is a major source of energy in Pennsylvania used by residential, commercial, and industrial customers. On June 22, 1999, the Natural Gas Choice and Competition Act, 66 Pa. C.S. 2801-2812 was enacted. This act opened the natural gas market in Pennsylvania to competition for the first time, allowing customers to choose who supplies their natural gas based on price, services, and incentives. The act also requires that the Pennsylvania Public Utility Commission create and maintain a program to help low income utility customers to afford gas service, as well as ensuring that all utility distribution territories are serviced and minimum energy conservation policies are in place and adequately funded throughout the state.

While there are not many natural gas efficiency programs currently in action in Pennsylvania, PECO Energy Company began offering a rebate program starting in January 2009. PECO offers rebates ranging from $50-300 for customers who replace their aging, inefficient furnaces, boilers and water heaters with new ENERGY STAR qualified appliances.

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[3] Pennsylvania Power Company is currently the only utility in the state in the Midwest ISO, though Duquesne Light Company in the Pittsburgh area has also received conditional approval from FERC to transfer to the Midwest ISO (PUC 2008b).

Fuel Oil and Propane

In Pennsylvania, fuel oil is predominantly used for residential heating needs in rural areas. Because the price of fuel oil is set by the global market and is not regulated at the state or national level, customers can be greatly affected by price shifts. The last few years have seen prices rise and fall by a factor of nearly two. There are several programs available to homeowners in Pennsylvania that could help fuel oil and propane customers alleviate high energy bills through efficiency, including Keystone HELP which offers affordable energy efficiency financing and has recently expanded to include heating equipment rebates, West Penn Power's PA HomeEnergy program, which offers a pilot Home Performance with Energy Star pilot, as well as programs offered by the rural cooperative utilities.

The Office of the Attorney General in Pennsylvania suggests that fuel oil customers purchase oil from suppliers that offer price-cap programs to guard against sudden shifts in market price, or utilize pre-purchase programs that offer protection from surging prices. However, in 2008 – 09, fuel oil prices became increasingly unpredictable, and very few dealers remain willing to offer "lock-in" rates. In such a volatile market, it is essential that customers research their suppliers carefully and make educated decisions about purchases.

Role of Energy Efficiency, Demand Response, and Onsite Solar Energy

Pennsylvania tied for the 15th ranking in ACEEE's *2008 State Energy Efficiency Scorecard,* which ranks states on eight energy efficiency policy and performance criteria. The Commonwealth performs better in some categories than others. For example, the Commonwealth scores fairly well on its building energy code stringency, has some policies in place to encourage Combined Heat and Power (CHP), adopted California's vehicle tailpipe emissions standards, has policies in place to require energy efficiency in the state's own facilities and fleets, and has some state grant and loan programs in place to help consumers implement energy efficiency measures. In the categories of utility-sector or state public benefits programs, however, the state has not performed well due to the loss of demand-side energy efficiency programs for electricity customers since deregulation in the 1990s.

In 2004, Pennsylvania enacted the Alternative Energy Portfolio Standards Act, requiring the state's electric utilities to meet annual targets for "clean energy" resources, which start at about 4% per year and ramp up to 10% in years 15 and thereafter. Energy efficiency had been included as an eligible resource as part of the two-tiered alternative portfolio standard, however there was no minimum efficiency target and other allowable resources, mostly comprised of waste coal, has thus far met the entire goal without need for improved efficiency (PUC & DEP 2008). Recent legislation, however, has created enabling policies and funding for the Commonwealth to increase its utility-sector energy efficiency commitments. Governor Edward Rendell signed the Alternative Energy Investment Act into law on July 9, 2008, creating a $650 million energy fund (see Table 1 for a summary of the various components). In addition to the $500 bond issue, the law establishes a $150 million Consumer Energy Program, which includes $92.5 million that will support loans, grants, and rebates for up to 25% of the cost of energy efficiency improvements to homes and small businesses.

Table 1. Alternative Energy Investment Act – Summary of Components

$500 Million Bond Issue	*Appropriation of $40 million per year (2008/9 through 2037/8) to the Commonwealth Financing Agency to support bond issue, including the following components.*
$40 million	Ben Franklin Technology Partners for investments in early-stage companies developing alternative energy and energy efficiency technologies.
$25 million	Department of Environmental Protection (DEP) for pollution control technology projects.
$40 million	Department of Public Welfare for an emerging energy assistance fund for low-income customers.
$100 million	DEP for solar installation rebates to homeowners and small businesses.
$165 million	Commonwealth Financing Authority (CFA) to provide loans or grants to businesses or non-profit economic development organizations for clean energy projects.
$25 million	CFA for grants/loans to geothermal and wind projects.
$25 million	CFA to provide loans or grants for high performance buildings.
$80 million	CFA to provide loans or grants for solar energy production projects and solar manufacturing facilities.
$100 Million Consumer Energy Program	*Appropriation of $100 million over next eight fiscal years (2008/9 through 2015/16).*
$92.5 million	Department of Environmental Protection for grants, rebates, and loans for homeowners and small businesses for consumer energy conservation and efficiency projects.
$5 million	Home Energy Efficiency Loan Program
$2.5 million	Grants and loans for data center consolidation projects.

Source: Clark 2008

In addition, Governor Rendell signed Act 129 in October 2008, setting binding electricity savings targets for utilities and thus enabling efficiency programs in all parts of Pennsylvania needed to assist consumers in reducing the overall demand for electricity and cutting peak electricity demand. The law requires Pennsylvania utilities to meet 1% of its electricity sales from energy efficiency by May 2011 and 3% by May 2013, as a percentage of projected energy use from June 2009 through May 2010. The bill also requires utilities to reduce "peak demand" (the 100 hours of highest energy demand annually) by 4.5% by May 2013, as a percentage of peak demand from June 2007 through May 2008.

These recent actions will enable Pennsylvania to move up in the rankings in the State Energy Efficiency Scorecard, though substantial opportunities still remain. Act 129 targets electric utilities in the near-term, though long-term ramping up of programs will be crucial to meet expected increases in electricity demand in the state. Also, energy efficiency investments for natural gas, fuel oil, and propane consumers are not required under current legislation. In the energy efficiency policy analysis, we explore opportunities to tap into the energy efficiency resource potential available in Pennsylvania. In leading states, for example, energy efficiency is meeting 1 to 2% of the state's electricity consumption and 0.5% to 1% of natural gas consumption each year (Nadel 2007; Hamilton 2008) at a cost of about 3 cents per kWh (Kushler, York and Witte 2004), compared with a utility-avoided cost of about 6 to 10 cents per kWh in Pennsylvania (see Figure 10).[4]

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[4] An assessment of marginal avoided natural gas costs was not undertaken as part of this analysis.

PROJECT APPROACH AND METHODOLOGY

Overall Project Approach

Over the past few years, ACEEE has worked increasingly at the state level as a growing number of state legislatures and governors are showing interest and leadership in energy efficiency. ACEEE established a base for further state work with the publication of the *State Energy Efficiency Scorecard for 2006.*[5] This report ranked all 50 states based on several energy efficiency strategies, including: utility spending on energy efficiency programs and public benefits, energy efficiency resource standards (EERS), combined heat and power (CHP) programs, building energy codes, transportation policies, appliance efficiency standards, financial incentives, and state initiatives for research and development. A second edition of the report, *The 2008 State Energy Efficiency Scorecard*[6]*,* was published in October 2008, and ACEEE plans to continue to update the *Scorecard* on an annual basis.

Using the *Scorecard* findings, ACEEE identified several states on the cusp of implementing new energy efficiency strategies or expanding existing ones. These states became the focal point of ACEEE's State Clean Energy Resource Project, or SCERP[7]. The intent is to create a series of state assessments of efficiency resources and other clean energy strategies, and for ACEEE to serve as a center of information and expertise in order to support clean energy policies at the state level. This assessment for Pennsylvania is the latest in this series of reports.

SCERP uses a tripartite model in preparing its assessments. The first step is to identify and meet or hold calls with the appropriate stakeholders (in Pennsylvania this included the PUC, DEP and several other state and local government officials, electric utilities (PECO and PPL), energy efficiency experts in the state, and environmental groups) to discuss ideas, concerns, and priorities. Following the meetings with state constituents, ACEEE and its project team performed its analysis of the state's overall energy efficiency resource potential, and then make specific policy, regulatory and program suggestions that become the heart of the final report. The last step is the outreach to the identified stakeholders to share the results of the study, generally through a combination of press releases, conference presentations, and other communication tools. Copies of the report are made available at outreach events as well as on the ACEEE Web site.

Analysis Methodology

The following is a description of the energy efficiency analysis methodology:

- ***Reference Case Forecasts:*** The first step in conducting an energy efficiency potential study for Pennsylvania and the greater Pittsburgh and Philadelphia metro regions is to collect data and to characterize the state's current and expected patterns of electricity, natural gas, and fuel oil consumption over the study time period (2009-2025). In the next section of this document we describe the assumed reference forecasts for electricity, peak demand, natural gas, and fuel oil. Reference case avoided costs for electric utilities, developed by Synapse Energy and Economics, are described in this section along with projections of retail energy price forecasts. See Appendix A for detailed information.

- ***Energy Efficiency Resource Assessment:*** The energy efficiency resource assessment examines the overall potential in the state for increased cost-effective efficiency using technologies and practices of which we are currently aware (see Appendix B for detailed information). Cost-effectiveness is evaluated from the customer's perspective (i.e., a measure is deemed cost-effective if its cost of saved energy is less than the average

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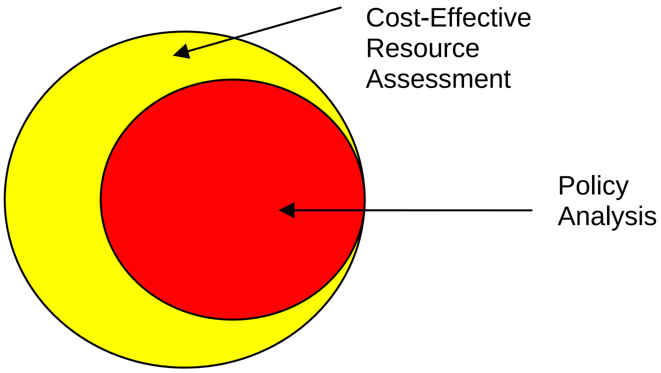
[5] The report is available at www.aceee.org/pubs/e075.htm.
[6] The report is available at www.aceee.org/pubs/e086.htm.
[7] See http://www.aceee.org/energy/state/scerp.htm.

retail rate of energy). We review specific, efficient technology measures that are technically feasible for each sector; analyze costs, savings, and current market share/penetration; and estimate total potential from implementation of the resource mix. The technology assessment is reported by sector (i.e., residential, commercial, and industrial) and includes an analysis of potential for expanded CHP, which is prepared by ICF International.

- ***Energy Efficiency Policy Analysis:*** For this analysis, we develop a suite of energy efficiency policy recommendations based on successful models implemented in other states and in consultation with stakeholders in Pennsylvania. This analysis assumes a reasonable program and policy penetration rate, and therefore is less than the overall resource potential (see Figure 2). We draw upon our resource assessment and evaluations of these policies in other states to estimate the energy savings and the investments required to realize the savings. The draft policy list for stakeholder review is presented after the reference forecast section in this document.

Figure 2. Levels of Energy Efficiency Potential Analysis



- ***Solar Assessment:*** The Vermont Energy Investment Corporation (VEIC) prepared an assessment of the potential for onsite solar technologies, including PV and solar air and water heating, in Pennsylvania and the metropolitan regions.

- ***Demand Response (DR) Analysis:*** The Demand Response Analysis, which is prepared by Summit Blue Consulting, assesses current demand response activities in Pennsylvania, uses benchmark information to assess the potential for expanded activities in the Commonwealth, and offers policy recommendations that could foster DR contributing appropriately to the resource mix in Pennsylvania that could be used to meet electricity needs. Potential load reductions are estimated for a set of DR programs that represent the technologies and customer types that span a range of DR efforts, and are in addition to the demand reductions resulting from expanded energy efficiency investments.

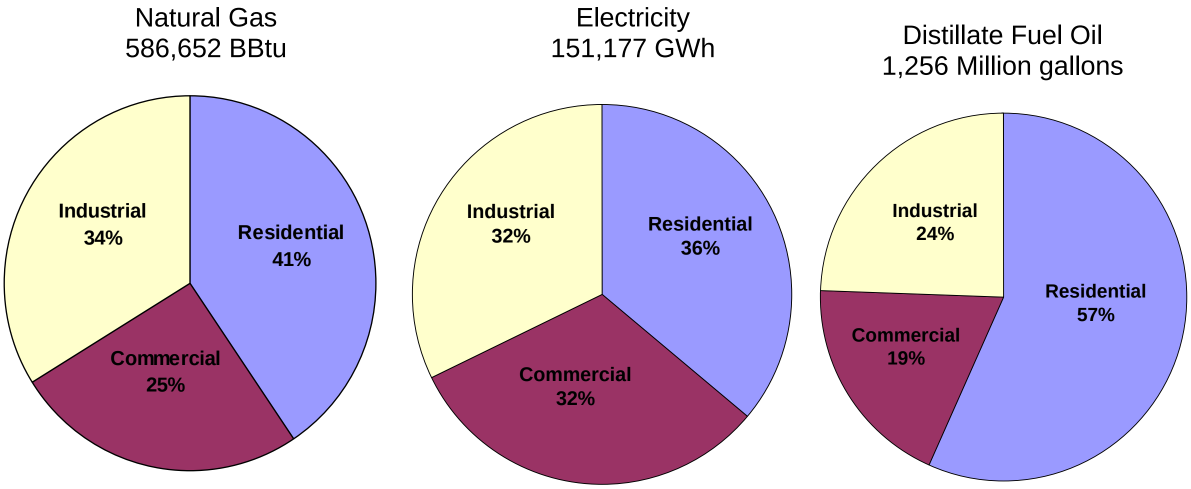
- ***Regional Impacts:*** Based on the findings of the energy efficiency policy, demand response, and onsite solar energy analyses, we then estimate energy savings for the greater Philadelphia and Pittsburgh metro regions and suggest additional policy opportunities at the local level.

- ***Macroeconomic Impacts:*** Based on the energy savings, program costs, and investment results from the policy analysis, we then run ACEEE's macroeconomic model, DEEPER, to estimate the policy impacts on jobs, wages, and gross state product (GSP) in Pennsylvania.

REFERENCE CASE

This section describes current and projected energy consumption, under a business-as-usual scenario, in Pennsylvania and the Philadelphia and Pittsburgh metropolitan regions by sector for electricity, natural gas, heating fuel, and propane. Current statewide consumption values are based on data from the Energy Information Administration (EIA) by end-use sector (see Figure 3) and projected "business as usual" forecasts are derived from several sources, including the Pennsylvania PUC's Electric Power Outlook (PUC 2008b), PJM Interconnection, and EIA's *Annual Energy Outlook.* For Philadelphia and Pittsburgh, current consumption values are derived from PA utility data by county and forecasts are derived from PJM forecasts by utility (PJM 2008a). For more detailed information on the reference case and methodology, see Appendix A.

Figure 3. 2007 Energy Consumption in Pennsylvania by End-Use Sector

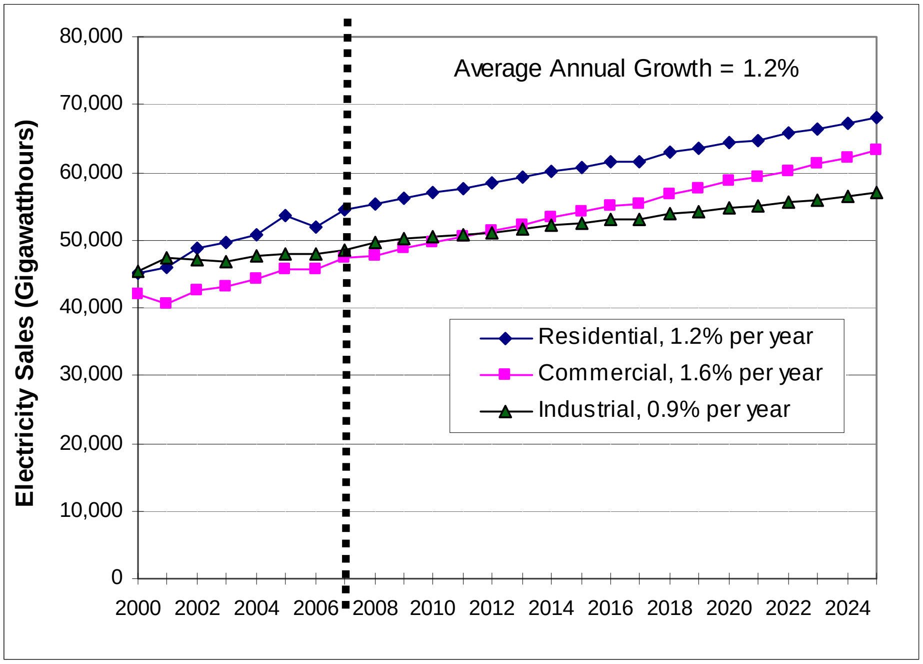


Pennsylvania

Electricity (GWh) and Peak Demand (MW)

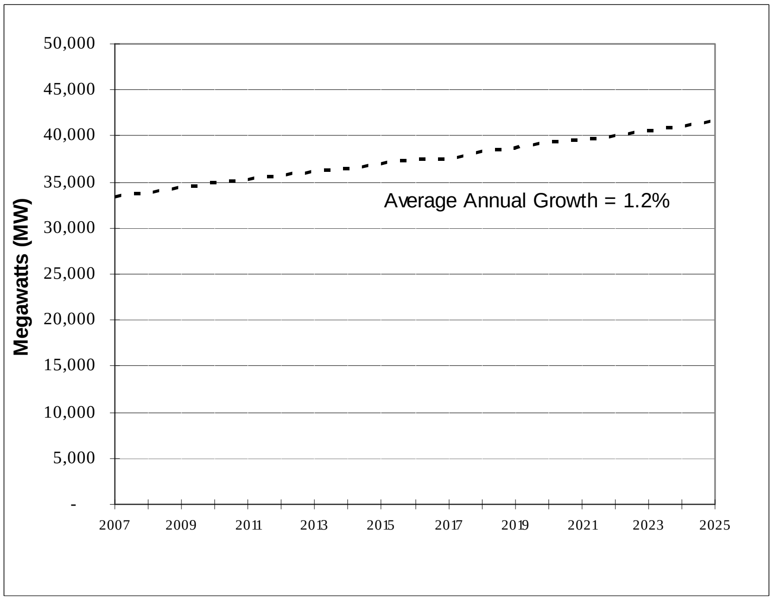
Pennsylvania's forecast of electricity consumption is based on 2007-year actual sales (151,117 GWh) reported to the Energy Information Administration (EIA 2008a) and near-term annual growth rates from the Pennsylvania Public Utilities Commission's (PUC) forecast for the years 2007-2012 (PUC 2008b. A growth rate from PJM's 2008 annual load forecast data, constrained to only PA electric service territories, extends the PUC's forecast to 2025 (PJM 2008a). Sector-specific growth rates are then determined using the Annual Electricity Outlook for the Mid-Atlantic region (EIA 2008b). The most recent data from EIA indicates that Pennsylvania electricity sales in 2008 in fact declined about 0.5% compared to sales in 2007, due in part to the economic slowdown, though this effect was not taken into account in our analysis base year of 2007, which was the most recently available data. Although there is a recent slowdown in electricity consumption in 2008, for purposes of this long-term analysis ACEEE estimates that total electricity consumption in the state is projected to grow in the reference case from 151,177 GWh in 2007 to 188,217 GWh in 2025, for an average annual growth rate of 1.2%, and 1.2%, 1.6%, and 0.8% in the residential, commercial, and industrial sectors, respectively (Figure 4).

Figure 4. Pennsylvania Electricity Sales (GWh) Forecast by Sector



The peak demand forecast is also based on the PUC's short-term projections and projections past 2012 using PJM's load growth forecasts (PJM 2008a). Peak demand in Pennsylvania is forecasted to rise in the reference case at an average annual rate of 1.2% between 2008 (the analysis base year) and 2025 (Figure 5).

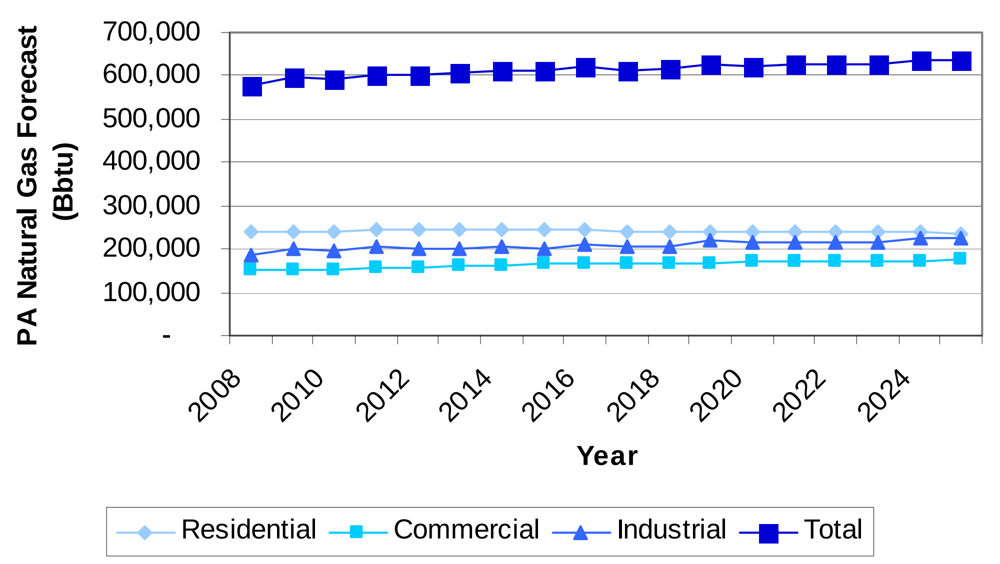
Figure 5. Peak Demand Reference Case Forecast (MW)



Natural Gas (BBtu)

EIA’s reported natural gas delivered to residential, commercial and industrial Pennsylvania customers in 2007 is the base value for Pennsylvania's natural gas consumption forecast (EIA 2007a). Base values for the year 2007 are then projected to 2025 by applying natural gas consumption growth rates from EIA's Annual Energy Outlook for the Mid Atlantic (EIA 2008b). Total natural gas consumption in the state is projected to grow in the reference case at an average annual rate of 0.6% between 2008 (the analysis base year) and 2025, and -0.1%, 0.9%, and 1.2% in the residential, commercial, and industrial sectors, respectively (see Figure 6).

Figure 6. Natural Gas Reference Case Forecast (2008-2025)



Fuel Oil (Mgal)

EIA's Petroleum State Profiles details Pennsylvania's actual consumption of distillate fuel oil by sector in 2006 (EIA 2006a). Growth rates from EIA's *Annual Energy Outlook* for the Mid-Atlantic region are then applied to 2006's actual consumption to obtain a forecast out to 2025 (EIA 2008b). Distillate fuel oil consumption in the state is projected to fall in the reference case at an average annual rate of -0.5% between 2008 (the analysis base year) and 2025, and change at -0.6%, 0.2%, and -0.8% in the residential, commercial, and industrial sectors respectively (Figure 7).

Propane (Mgal)

Pennsylvania's propane forecast begins with estimating 2005 propane consumption from the *Residential Energy Consumption Survey* (RECS) available through EIA. When combined with the number of households in Pennsylvania from Economy.com, RECS data detailing the percentage of all homes that use propane to heat their homes and gallon per household usage of propane provided residential baseline consumption of propane. A growth rate from EIA's *Annual Energy Outlook* was then applied to the 2005 baseline value to obtain a forecast to 2025. Between 2008 (the analysis base year) and 2025, residential propane consumption in the reference case is expected to increase 0.4%. Estimated residential propane consumption was at 94.9 Mgal in 2008 and 101.5 Mgal in 2025 (see Figure 8).

Figure 7. Fuel Oil Reference Case Forecast

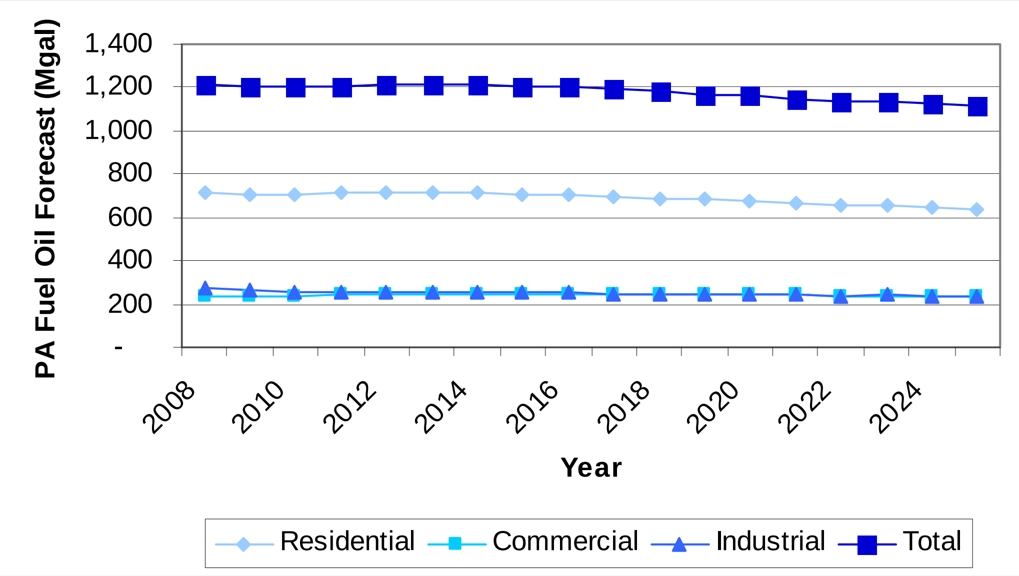
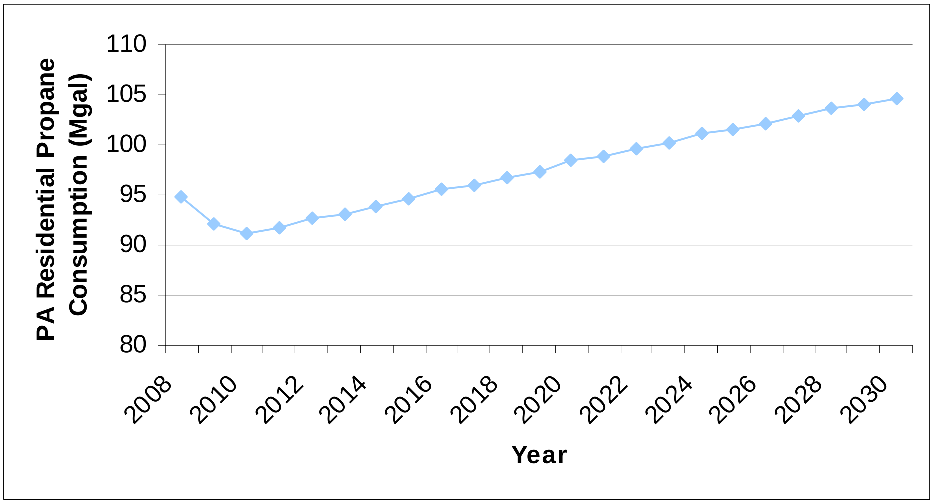


Figure 8. Pennsylvania Residential Propane Consumption Forecast 2008-2025



Philadelphia and Pittsburgh

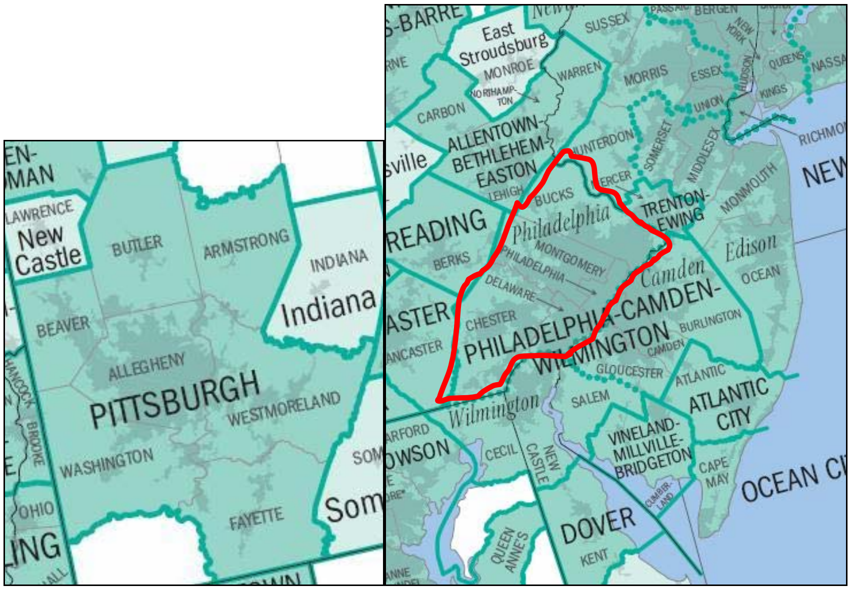
For the purposes of this analysis, the Philadelphia and Pittsburgh metropolitan areas are defined at the county level. The U.S. Census Bureau defines Philadelphia and Pittsburgh regions as Metropolitan Statistical Areas (MSA), which include the entirety of several counties. For this analysis, Pittsburgh is defined as the U.S. Census MSA and in the case of Philadelphia, only those counties that reside in Pennsylvania (does not include Delaware and New Jersey counties) are included in the definition (see Figure 9).

Philadelphia includes the following counties: Bucks, Chester, Delaware, Montgomery, and Philadelphia. These counties are served by the following electric utilities: PECO Energy (Exelon), PPL Electric, and Metropolitan Edison; and natural gas utilities: Columbia Gas, Equitable Gas, Dominion Peoples, Philadelphia Gas Works, TW Philips, Herman Oil & Gas, National Fuel and Gas.

The US Census Bureau MSA for Pittsburgh includes the counties of: Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, and Westmoreland. These counties are served by the electric utilities: Duquesne Light Company, West Penn Power, Penn Power (MetEd/FirstEnergy), and Pennsylvania Electric Company; and natural gas utilities: Columbia Gas, Equitable Gas, Dominion Peoples, TW Philips, Herman Oil & Gas, National Fuel and Gas.

It is important to note that several electrical and natural gas utilities in both MSAs serve customers outside of the defined MA counties. Also, a utility that serves an MA may not serve all counties within an MA. For these reasons it was necessary to review each utility's year-end report for 2007, available from the Pennsylvania PUC (PUC 2007a&b), and evaluate how many customers were served within those counties in a Pennsylvania MA. These annual reports also provide the utility's total sales, by multiplying the amount of sales by the percent of customers the utility served in the MA, we were able to separate the sales a utility provided only to the MA. So, if only 75% of the utility's customers were in the MA, 75% of their total sales were attributed to the MA, keeping the allocation across the residential, commercial and industrial sectors constant. The methodology provides a base year from which a growth rate is applied to achieve a forecast for the specified MA.

Figure 9. Philadelphia and Pittsburgh Metropolitan Areas



Source: U.S. Census Metropolitan Statistical Areas. The highlighted Pennsylvania counties of the Philadelphia MSA comprise the region studied for this analysis.

Electricity (GWh)

To project electricity consumption to 2025 for Pittsburgh, growth rates from PJM's annual load forecast data for Duquesne Light Company (which supplies nearly 90% of Pittsburgh's electricity) were applied to the base year (PJM 2008a). Growth rates from PJM's annual load forecast data for PECO Energy (which supplies 96% of Philadelphia's electricity) were applied to the base year to obtain projected electricity consumption to 2025 for Philadelphia (PJM 2008a). Pittsburgh electrical consumption in the state is projected to grow in the reference case at an average annual rate of 0.9% between 2008 (the analysis base year) and 2025. Philadelphia electrical consumption in the state is projected to grow in the reference case at an average annual rate of 1.4% between 2008 (the analysis base year) and 2025.

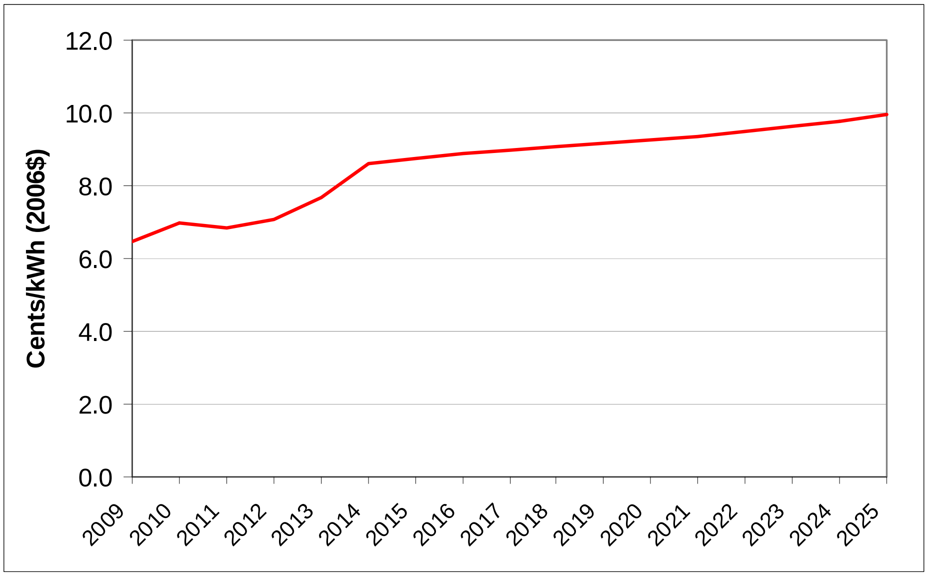
Projections of natural gas and fuel oil consumptions in the metro regions are estimated follow similar patterns to statewide projections and are shown in Appendix A.

Avoided Utility Costs

At ACEEE's request, Synapse Energy Economics developed simplified, high-level projections of electricity utility production and avoided marginal costs. We then used these results in ACEEE's analysis to estimate the cost-effectiveness of energy efficiency measures and assess the macroeconomic impacts. The avoided cost estimates are based upon a number of simplifying and conservative assumptions considered reasonable for the purpose of this high-level policy study. These simplifications include use of a single annual average avoided energy cost to evaluate the economics of energy efficiency measures rather than different avoided energy costs for energy efficiency measures with different load shapes. The estimates also assume a future cost of carbon emissions, increasing from $15 per ton in 2013 to about $50 per ton in 2025 (in constant 2006$), which is based on analysis by Synapse Energy Economics. We also did not undertake an assessment of the marginal avoided costs for natural gas. A detailed discussion of the assumptions and avoided electricity cost estimates can be found in Appendix A.

It is important to note that because these projections represent a highly stylized representation of costs, we suggest that a more detailed assessment of costs be undertaken as part of the Commonwealth's energy planning process that can reflect the locational and temporal variation across the state and throughout the year.

Figure 10. Estimates of Average Annual Avoided Electricity Resource Costs in Reference Case



Retail Prices

ACEEE also developed a possible scenario for retail electricity and natural gas prices in the reference case. Readers should note the important caveat that ACEEE does not intend to project future electricity prices in Pennsylvania for either the short or the long-term. Rather, our goal is to suggest a possible scenario, based on data from credible sources, and to use that scenario to estimate impacts from energy efficiency on customers in Pennsylvania.

Table 2 shows 2007 actual electricity prices in Pennsylvania (EIA 2008a) and our estimates of retail rates by customer class over the study period. This price scenario is based on two key factors. First, we use the average generation cost of electricity in Pennsylvania over the study period as calculated by Synapse Energy Economics (see above). Next, we use estimates of retail rate adders (the difference between generation costs and retail rates, which accounts for transmission and distribution costs) from the *Annual Energy Outlook* for the East Central Area Reliability Coordination Agreement (ECARC) (EIA 2008b). Finally, we adjust near-term prices based on recent utility filings in the Commonwealth.

Table 2. Retail Electricity Price Forecast Scenario in Reference Case (cents per kWh in 2006$)

	2007*	**2010**	**2015**	**2020**	**2025**	**Average**
Residential	11.0	11.5	12.1	12.9	13.6	**12.4**
Commercial	9.2	9.4	10.3	11.1	11.8	**10.4**
Industrial	6.9	7.0	7.6	8.3	9.0	**7.8**
All Sector Average	9.1	9.1	10.5	11.2	12.0	**10.5**

Note: These figures are in real, 2006-year dollars and therefore do not take into account inflation.
* Actual rates (EIA 2008a), converted to 2006$

ACEEE also developed a possible scenario for retail natural gas prices in the reference case. We used long-term Henry Hub estimates developed by Synapse Energy Economics and then use estimates of retail rate adders (the current difference between Henry Hub and retail prices) to develop a retail price scenario. Based on this analysis, which was completed in November 2008, our scenario consisted of average natural gas prices of about $12 - 14 per million Btu to consumers in Pennsylvania over the 2008 – 2025 study time period. *Readers should note that wholesale natural gas prices have dropped substantially since the fall of 2008. Markets for natural gas remain volatile, however, so prices will again increase to a level significantly higher than today. See the next section on the estimates of energy efficiency potential for natural gas consumers for a further discussion of natural gas prices.*

ENERGY EFFICIENCY COST-EFFECTIVE RESOURCE ASSESSMENT

This section presents the results from our assessment of cost-effective energy efficiency resources in residential and commercial buildings, the industrial sector, and combined heat and power (CHP). Cost-effectiveness of more efficient technologies, compared to a standard baseline technology, is determined from the customer's perspective, i.e., a measure is deemed cost-effective if its levelized[8] cost of conserved energy (CCE) is less than the average retail energy price for a given customer class. Average CCEs for each sector are shown in the following sections. It is worth noting, however, that the overwhelming majority of efficiency measures are also less than the marginal avoided costs to electric utilities (see Figure 10). More detailed information on methodology and results is provided in Appendix B. Table 3 presents a summary of energy efficiency potential by sector in 2025. Readers should note that this assessment includes mostly existing technologies and practices, though we anticipate that new and emerging technologies and market learning will significantly increase the cost-effective energy resource by 2025.

Table 3. Summary of Cost-Effective Energy Efficiency Potential by Sector (2025)

	Electricity		Natural Gas and Propane		Fuel Oil	
Sector	GWh	%*	BBtu	%*	Mil. Gallons	%*
Residential	~19,000	10%	~91,000	14%	~260	23%
Commercial (non-CHP)	~18,000	9%	~46,000	7%	~60	6%
Industrial (non-CHP)	~13,000	7%	~37,000	6%	NA	NA
Combined Heat & Power	~11,000	6%	NA	NA	NA	NA
	~61,000	33%	~174,000	27%	~320	29%

*Note: Savings are represented as a percent of the projected reference case energy consumption in 2025.

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[8] Levelized cost is the level of payment necessary each year to recover the total investment over the life of the energy efficiency measure.

Residential

Electric

Our analysis of energy efficiency potential for Pennsylvania's residential electricity sector considered a scenario with widespread adoption of cost-effective energy efficiency measures during the 18-year period from 2008 to 2025. We evaluated 36 efficiency measures that can be adopted in existing and new single family and multifamily residential homes based on their cost-effectiveness. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy (CCE) is less than 12.35 cents per kWh saved, the average retail residential electricity price in Pennsylvania over the study time period (EIA 2008b). It is worth noting that 99% percent of the economic potential from the customer's perspective is also less than 8.6 cents per kWh, which is the average utility avoided electricity resource cost over the study time period (see Figure 10), and therefore also cost-effective from the utility perspective. Likewise, the substantial majority (86%) of the total efficiency potential has a levelized cost of 7 cents per kWh saved or less and 25% of the measures have a cost of 2 cents per kWh or less. We estimate a weighted levelized cost of less than 3 cents per kWh saved for all measures combined (see Table 4). See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for residential buildings.

Single-Family Homes

Table 4. Single Family Residential Energy Efficiency Potential and Costs by End-Use

End-Use	Savings (GWh)	Savings (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/kWh)
Improved Housing Shell Performance	5,690	10%	32%	$ 0.021
HVAC Equipment Measures	790	1%	4%	$ 0.005
Water Heating	2,270	4%	13%	$ 0.035
Lighting	3,770	6%	21%	$ (0.003)
Refrigeration	410	0.7%	2%	$ 0.060
Appliances	110	0.2%	1%	$ 0.077
Furnace Fans	1,050	2%	6%	$ 0.047
Plug Loads	840	1%	5%	$ 0.024
Electricity Use Feedback	1,250	2%	7%	$ 0.052
Existing Homes	16,190	27%	90%	$ 0.026
New Homes	1,740	3%	10%	$ 0.043
All Electricity	17,930	30%	100%	$ 0.028

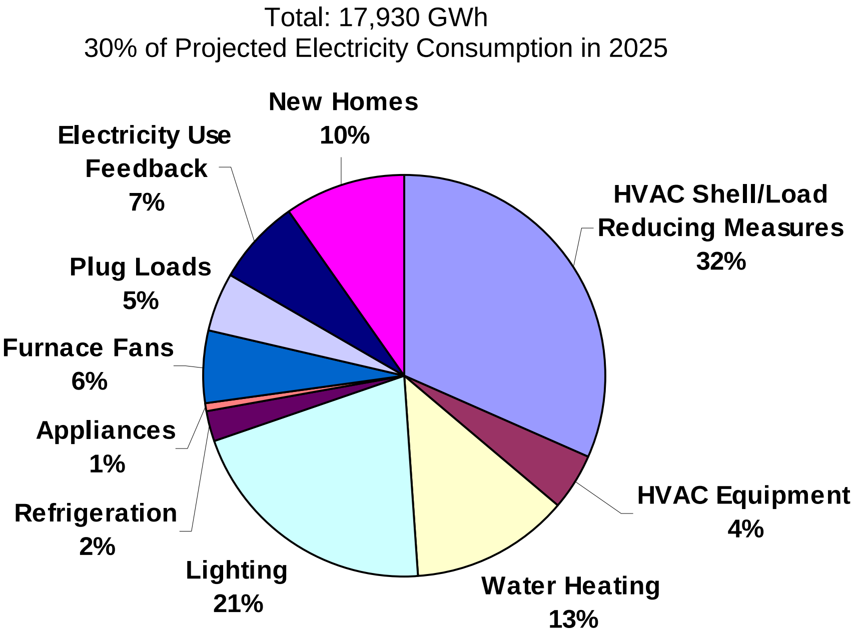
For single family houses, we estimate an economic potential for efficiency resources of nearly 18,000 GWh over the 18-year period of 2008–2025, a potential savings of 30% of the reference case electricity consumption in 2025 (see Table 4). Existing homes can reduce electricity consumption by 27% through the adoption of a variety of efficiency measures (see Appendix B, Table B-1), while newly constructed homes built today can achieve another 15% energy savings (ENERGY STAR® new homes meet this level of efficiency). We also estimate that new homes can reach 30% to 50% energy savings cost-effectively. We estimate that new single family homes can yield electricity savings of about 1,700 GWh by 2025, or 3% of total potential energy savings in the residential sector.

In the residential sector, the majority of savings from electricity efficiency resources are realized through improved housing shell performance (e.g., insulation measures, duct sealing and repair, reduced air infiltration, and ENERGY STAR windows) and more efficient heating, ventilation, and air conditioning (HVAC) equipment and systems. HVAC equipment, air distribution, efficient furnace fans, and improved housing shell performance measures account for 36% of potential savings.

Substantial savings are also attributed to improvements in lighting systems and water heating (including both more efficient water heaters as well as water-consuming appliances). As a fraction of total savings potential in the residential sector, lighting constitutes 21% and water heating 13% of potential savings (see Table 4). There is considerable potential for efficiency resources in both existing and new homes in Pennsylvania to be realized simply by replacing household incandescent light bulbs with more efficient compact fluorescent light bulbs (CFLs). Emerging LED lighting technologies offer the potential for additional significant energy savings, but are not yet cost-effective and are therefore not included in this study. However, future studies will likely include this promising measure. Measures to reduce hot water loads (such as high-efficiency clothes washers, low-flow showerheads, and water heater jackets and pipe insulation) can yield additional savings for households with electric water heaters. The use of more efficient water heaters, particularly advanced technologies such as heat-pump water heaters, can further reduce electricity used for water heating.

The adoption of more efficient furnace fans offers Pennsylvania residents another avenue for significant energy savings. Our analysis shows a 6% energy savings potential of replacing existing PSC furnace fans with units that meet or exceed minimum ECM standards. Another 5% of the total savings potential can be realized through reducing the power consumption of electronic devices that use considerable amounts of energy in standby mode. We include a measure for reducing television power consumption in active mode, which is based on ENERGY STAR's Draft 2 Specification revision. These measures are among the most cost-effective in the residential sector. The balance of potential savings comes from installing a real-time energy use feedback mechanism. Although involving a behavioral component, in-home monitors, which allow residents to track how much electricity their house is using, have been documented to result in significant and persistent savings. Recent utility bill feedback comparing a customer's monthly consumption to that of comparable homes in their neighborhood and to energy efficient neighbors is also very promising. There are additional behavioral or conservation steps that everyone can take to reduce energy use, but our study focuses specifically on energy efficiency measures as compared to a baseline non-efficient measure. For example, an oft-overlooked action that many can take is switching off power strips when connected appliances are not in use. As evident in our plug load measure analysis, there is incredible potential for energy savings through load reduction of appliances that are not in use.

Figure 11. Single-Family Residential Electricity Energy Efficiency Potential in 2025 by End-Use in Pennsylvania



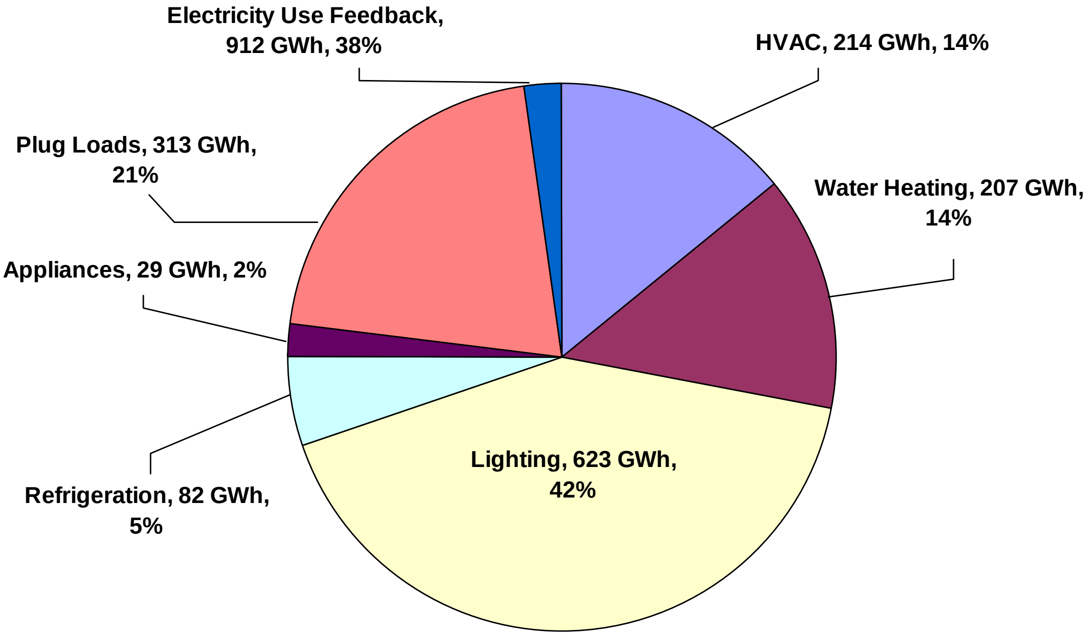
Multifamily Homes

Table 5. Multifamily Residential Energy Efficiency Potential and Costs by End-Use

End Use	Savings (GWh)	Savings (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/kWh)
HVAC Equipment	210	2%	14%	$ 0.01
Water Heating	210	2%	14%	$ 0.07
Lighting	620	7%	42%	$ 0.06
Refrigeration	80	1%	5%	$ 0.05
Appliances	30	0.3%	2%	$ 0.08
Plug Loads	310	4%	21%	$ 0.03
Electricity Use Feedback	30	0.4%	2%	$ 0.07
All Electricity:	1,500	17%	100%	$ 0.05

For multifamily buildings, we analyzed the potential savings using fourteen cost-effective efficiency measures. We estimate a total economic potential for cost-effective efficiency resources of 1,500 GWh, or 17% of the reference case consumption for multifamily buildings in 2025. Forty two percent of the total savings stem from lighting, which involves the installation of occupancy sensors as well as replacing lighting in living units as well as in common areas, such as hallways, stairwells, etc. Significant savings can also be realized through upgrading HVAC and water heating systems, as well as reducing plug loads through the use of more efficient consumer electronics with standby electricity consumption equivalent to 1 watt.

Figure 12. Multifamily Residential Electricity Energy Efficiency Potential in 2025 by End-Use in Pennsylvania



Natural Gas

The majority of residences in Pennsylvania use natural gas to heat their homes (EIA 2003). To examine the potential for energy efficiency resources for this portion of Pennsylvania's population, we assumed a scenario of 25 cost-effective measures for single-family buildings and 22 cost-effective measures for multifamily buildings. Upgrading to a new, more efficient measure is considered cost-effective if its levelized cost of conserved energy is less than $14.25 per MMBtu, which is the average retail price for natural gas in Pennsylvania over the 2009-2025 time period in the analysis reference case scenario. For all efficiency measures combined, we estimate a weighted average levelized cost for efficiency of $5.29 per MMBtu saved (see Table 6). *Readers should note that wholesale natural gas prices have dropped significantly since the reference case was developed for this analysis. Markets for natural gas remain volatile, however, so prices will again increase to a level significantly higher than today and at least consistent with those seen from 2006 to 2007. Because this is a long-term analysis, the findings remain plausible. In addition, market pressures and/or policies such as a carbon tax could create even greater upward pressure on prices in the next decade.*

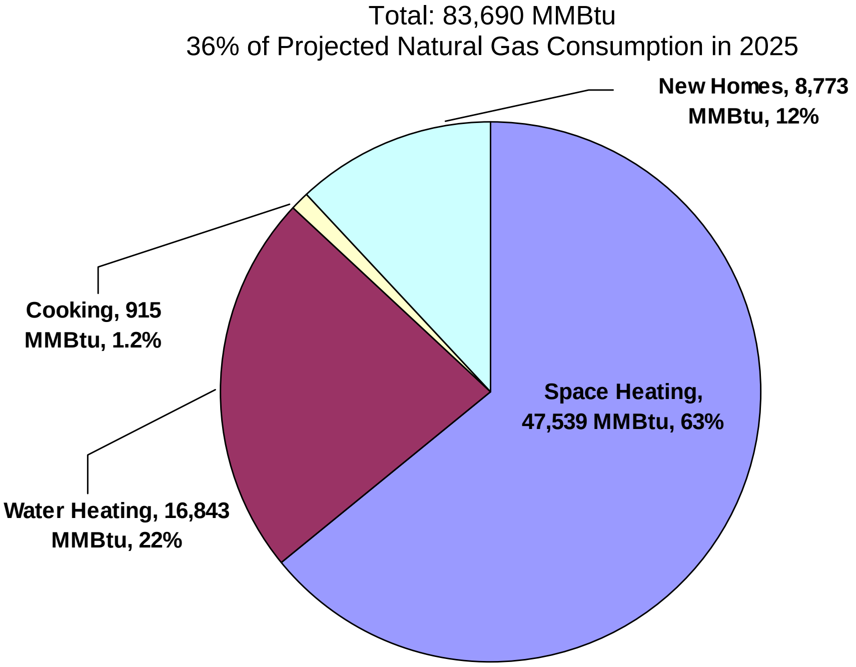
Table 6. Residential Natural Gas Efficiency Potential and Costs by End-Use (2025)

End-Use	Savings (MMBtu)	Savings relative to Reference Case (%)	% of Total Efficiency Potential	Levelized Cost of Saved Energy ($/MMBtu)
Single Family Gas	**74,070**	**35%**	**100%**	**$5.01**
Space Heating	47,540	22%	64%	$3.70
Water Heating	16,840	8%	23%	$7.90
Cooking	920	0.4%	1%	$9.34
Existing	65,300	30%	88%	$4.86
New Homes	8,770	4%	12%	$4.82
Multifamily Gas	**9,620**	**46%**	**100%**	**$7.47**
Space Heating	4,350	20%	45%	$6.86
Water Heating	3,360	16%	35%	$3.04
Cooking	100	0.5%	1%	$11.71
Existing	7,810	37%	81%	$5.28
New Homes	1,810	9%	19%	$9.40
All Residential Gas	**83,690**	**36%**	**100%**	**$5.29**
Space Heating	51,890	22%	62%	$3.96
Water Heating	20,200	9%	24%	$7.09
Cooking	1,010	0.4%	1%	$9.57
Existing	73,10	31%	87%	$4.91
New Homes	10,590	5%	13%	$5.61

Through the implementation of 25 cost-effective measures as shown in Appendix B, single family homes in Pennsylvania can save 35% of their baseline natural gas consumption. Multifamily buildings, by implementing the 22 cost-effective measures, can save 46% of their baseline natural gas consumption. Aggregating baseline consumption and savings for single and multifamily buildings shows that Pennsylvania can achieve about 36% savings in the residential sector, or 83,690 MMBtu of natural gas.

The vast majority of savings in the residential sector are attributed to improvements that reduce natural gas consumption dedicated to space heating, such tightening up the home envelope (e.g., insulation measures, duct sealing and repair, reduced air infiltration, and ENERGY STAR windows) and investing in more efficient heating and ventilation equipment and systems. These load-reducing measures and equipment upgrades account for 62% of the natural gas savings potential. A significant amount of savings can also be realized through improvements to the water heating system, either through load-reducing measures (such as low-flow showerheads, and water heater jackets and pipe insulation) or by upgrading water heating equipment. Appliance upgrades, such as efficient clothes washers and dish washers, can also contribute to reductions in hot water consumption. As a percent of the total natural gas savings potential in the residential sector, improvements to the water heating system can reduce consumption by 24%, or 20,200 MMBtu.

Figure 13. Single-Family Electricity Energy Efficiency Potential in 2025 by End-Use in Pennsylvania



Fuel Oil

To examine the potential for energy efficiency resources in Pennsylvania's residential sector, a scenario of 44 cost-effective measures for fuel oil savings are adopted during the 18-year period from 2008 to 2025. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy (CCE) is less than $2.50 per gallon saved, which is the average retail fuel oil price in Pennsylvania over the study time period. We estimate a weighted average levelized cost for efficiency of $0.63 per gallon saved (see Table 7). See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for residential buildings (see Appendix B, Tables B-5 & B-6).

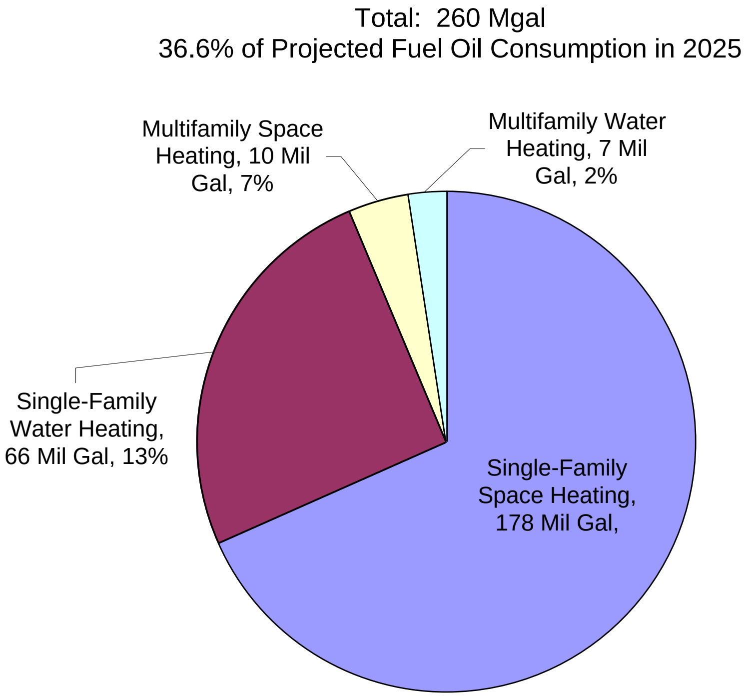
Single family homes can reduce fuel oil consumption by 37% through the adoption of a variety of efficiency measures. Multifamily homes can save 32% relative to the baseline fuel oil consumption through 2025. As a whole, the economic potential for efficiency resources in the residential sector can save 37% for a potential savings of 260 Mgal through the period 2008-2025.

Table 7. Residential Fuel Oil Efficiency Potential and Costs by End-Use (2025)

End-Use	Savings (Mgal)	Savings relative to Reference Case (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/gallon)
Single Family Oil	243	37%	100%	$0.56
All Space Heating[9]	178	27%	73%	$0.63
Water Heating	66	10%	27%	$0.36
Multifamily Oil	17	32%	100%	$1.51
All Space Heating[10]	10	20%	60%	$1.16
Water Heating	7	13%	39%	$2.13
All Residential Oil	**260**	**37%**	**100%**	**$0.63**
Space Heating Total[11]	188	26%	72%	$0.66
Water Heating Total	72	10%	28%	$0.52

In the residential sector, fuel oil savings from efficiency resources are realized through improved housing shell performance (e.g., insulation measures, duct sealing and repair, reduced air infiltration, and ENERGY STAR windows) and more efficient heating and ventilation equipment and systems. These load reduction measures account for 72% of potential savings. Measures to reduce hot water loads (such as low-flow showerheads, and water heater jackets and pipe insulation) can yield additional savings for households with electric water heaters. The use of more efficient water heaters further reduces electricity used for water heating. Water heating constitutes 28% of the total savings potential in residential buildings (see Figure 14).

Figure 14. Residential Fuel Oil Efficiency Potential in 2025 by End-Use in Pennsylvania



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[9] All space heating includes measures improved housing shell performance and equipment efficiency for forced air, steam boilers, and water boilers.

[10] Ibid.

[11] Ibid.

Propane

To examine the potential for propane savings from efficiency in Pennsylvania's residential sector, a scenario of 12 cost-effective measures for propane savings are adopted during the 18-year period from 2008 to 2025. An upgrade to a new measure is considered cost-effective if its levelized cost[12] of conserved energy (CCE) is less than $2.86 per gallon saved, which is the average retail price for propane in Pennsylvania over the study time period (Reference Price Forecast). For the sum of all measures, we estimate a levelized cost of less than $0.80 per gallon saved (see Table 8). See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for residential buildings (see Appendix B, Table B-7).

Table 8. Residential Propane Efficiency Potential and Costs by End-Use

End-Use Category	Savings (Mgal)	Savings over Reference Case (%)	% of Efficiency Potential	Cost of Saved Energy ($/gallon Saved)
Space Heating	21	21%	72%	$ 0.83
Water Heating	5	5%	18%	$ 0.83
Appliances	3	3%	11%	$ 0.22
All Propane	29	29%	100%[13]	$ 0.76

Single family homes can reduce propane use by 29% in 2025. By adopting space heating, water heating and appliances measures single family homes will save over 29 million gallons of propane.

Homes which adopt improved appliances, like more efficient clothes dryers and electronic ignition stoves, can save Pennsylvania 3 million gallons of propane. Measures to reduce water heating loads, such as pipe insulation and high-efficiency showerheads, combined with installation of more efficient water heating equipment saves 5 million gallons of propane in 2025. The largest opportunity for propane savings comes from space heating measures. The adoption of more efficient heating equipment, improved insulation, and ENERGY STAR windows, provide 72% of the total propane savings available to consumers in 2025. By adopting these measures, over 21 Mgal of propane can be saved (Figure 15).

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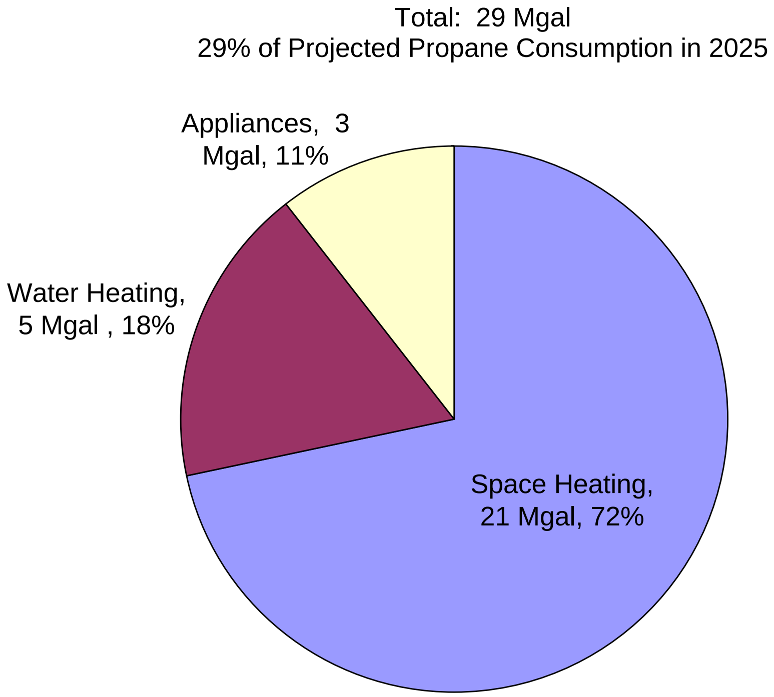
[12] Levelized cost is a level of investment necessary each year to recover the total investment over the life of the measure.

[13] Due to rounding errors, end-use efficiency potential in this chart does not sum to 100%.

Figure 15. Residential Propane Efficiency Potential in 2025 by End-Use in Pennsylvania



Commercial

Electricity

The potential for electricity savings through energy efficiency in Pennsylvania is examined through a scenario of 37 cost-effective measures for electricity savings which would be adopted during the 17-year period from 2009 to 2025. An upgrade to a new measure is considered cost-effective if its levelized cost[14] of conserved energy (CCE) is less than 10 cents per kWh saved, which is the average retail electricity price in Pennsylvania over the study time period (Reference Price Forecast). For the sum of all measures, the estimated levelized cost is 1.2 cents per kWh saved (Table 9). See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for commercial buildings (see Table B-10).

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[14] Levelized cost is a level of investment necessary each year to recover the total investment over the life of the measure.

Table 9. Commercial Electricity Efficiency Potential and Costs by End-Use

End-Use	Savings (GWh)	Savings over Reference Case (%)	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/kWh)
Heating & Cooling (building shell)	1,140	2%	6%	$ 0.013
Heating & Cooling (equipment & controls)	2,600	4%	14%	$ 0.028
Water Heating	160	< 1%	1%	$ 0.033
Refrigeration	800	1%	4%	$ 0.017
Lighting	9,670	15%	53%	$ 0.006
Office Equipment	3,090	5%	17%	$ 0.003
Appliances and Other	20	< 1%	0%	$ 0.033
Existing Buildings	17,500	28%	95%	$ 0.012
New Buildings	910	1%	5%	$ 0.012
Total Electricity	18,400	29%	100%	$ 0.012

Commercial buildings can reduce electricity consumption by 29% through the adoption of a variety of efficiency measures. The economic potential for efficiency resources in the commercial sector will reduce electricity use by 18,400 GWh through the period 2008-2025.

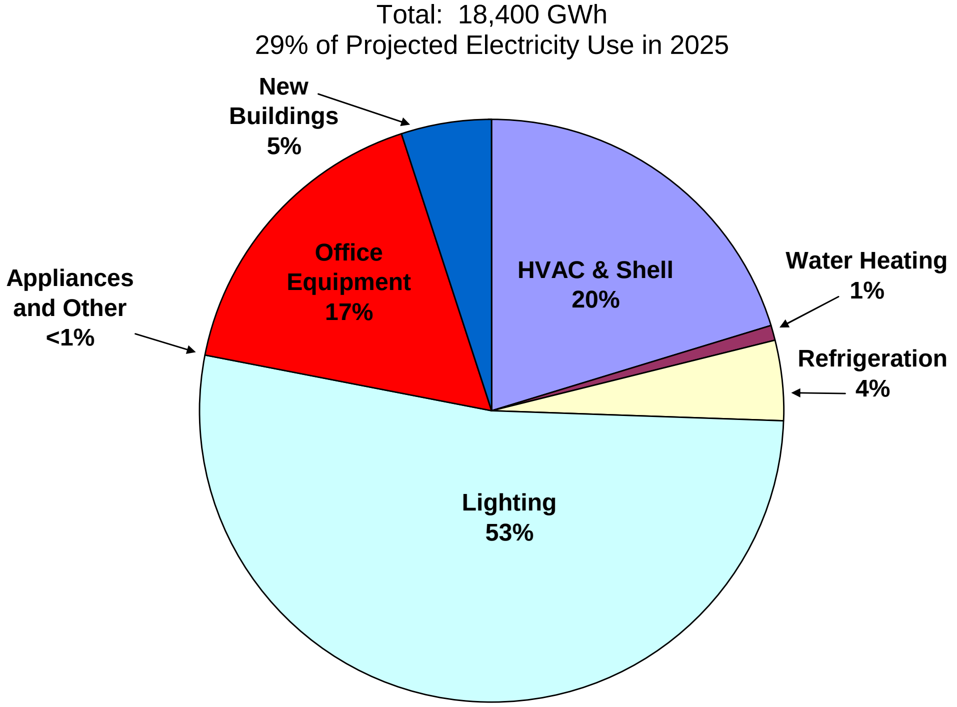
In the commercial sector, electricity savings from efficiency resources are realized through improved HVAC equipment, controls and building shell measures (e.g., roof insulation and new windows); improved water heating (e.g., heat pump water heaters); more efficient refrigeration systems (e.g., ENERGY STAR vending machines); and efficient lighting, office equipment, and miscellaneous appliances. The largest share of the savings, at 47%, is improved lighting efficiency. This includes more efficient light bulbs such as fluorescent and HID, improved lighting controls such as daylight dimming systems and occupancy sensors, and certain LED applications such as task lighting.

HVAC and office equipment also provide substantial savings, at 21% and 18% respectively. Shell measures include roof insulation and improved windows. HVAC measures include better heating and cooling systems (e.g., high efficiency chillers and heat pumps), and better controls (e.g., dual enthalpy controls and energy management system installations). Improved office equipment includes more efficient computers, printers, copiers, etc., as well as turning off this equipment after hours.

Water heating measures include heat pump water heaters, and efficient clothes washers, which reduce hot water demand. Refrigeration measures include improved commercial refrigeration systems (e.g., walk-in coolers, ice makers, vending machines).

For commercial new construction, we estimate that up to 50% savings can be reached cost-effectively (NREL 2008).

Figure 16. Commercial Electricity Efficiency Potential in 2025 by End-Use in Pennsylvania



Natural Gas

The potential for natural gas savings through energy efficiency in Pennsylvania's commercial building sector is examined through a scenario of 26 cost-effective measures for gas savings which would be adopted during the 18-year period from 2008 to 2025. An upgrade to a new measure is considered cost-effective if its levelized cost[15] of conserved energy (CCE) is less than $12.45 per MMBtu saved, which is the average retail natural gas price in Pennsylvania over the study time period in the reference case price forecast. *Readers should note that wholesale natural gas prices have dropped significantly since the reference case was developed for this analysis, however given the volatile nature of the market will again to rise to recent levels. See the discussion in the residential section.* For the sum of all measures, the estimated levelized cost is $3.28 per MMBtu saved (see Table 10), still cost-effective given today's low prices. See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for commercial buildings (see Table B-10).

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[15] Levelized cost is a level of investment necessary each year to recover the total investment over the life of the measure.

Table 10. Commercial Natural Gas Efficiency Potential and Costs by End-Use

End-Use	Savings (MMBtu)	Savings over Reference Case (%)	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/MMBtu)
HVAC equipment & controls	26,200,000	15%	54%	$ 2.39
Building shell	2,000,000	1%	4%	$ 0.30
Water Heating	5,400,000	3%	11%	$ 6.27
Cooking	4,000,000	2%	8%	$ 1.11
Other	7,200,000	4%	15%	$ 8.43
Existing Buildings	44,700,000	26%	93%	$ 3.19
New Buildings	3,500,000	2%	7%	$ 2.45
Total Gas	48,200,000	28%	100%	$ 3.28

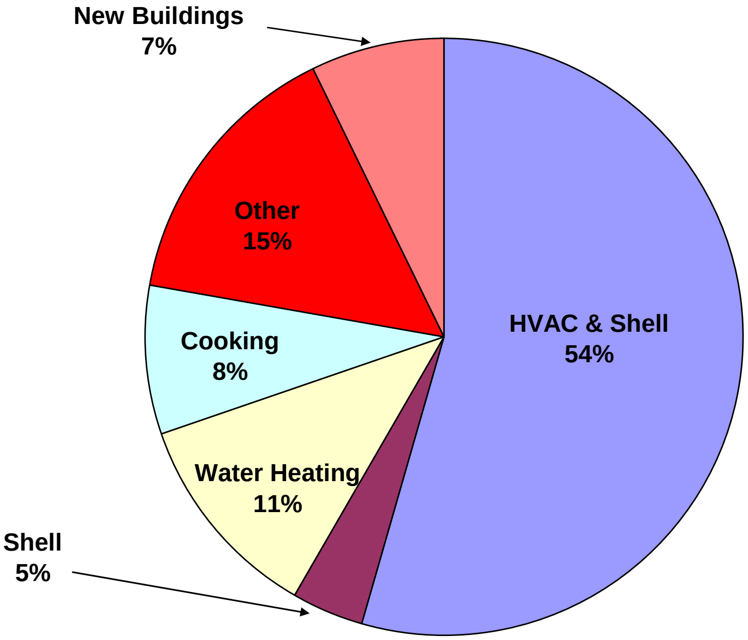
Commercial buildings can reduce natural gas consumption by 28% through the adoption of a variety of efficiency measures. The economic potential for efficiency resources in the commercial sector will reduce natural gas use by over 48 trillion Btu through the period 2008-2025.

In the commercial sector, gas savings from efficiency resources are realized through improved HVAC equipment, controls and building shell measures (e.g., duct sealing and pipe insulation); improved water heating (e.g., tankless water heaters); and more efficient cooking equipment (e.g., ENERGY STAR fryers). The largest share of the savings is improved HVAC measures, including heating system measures, and improved controls. Building shell measures include a roof insulation and low-e windows. Better heating equipment takes into account types of equipment appropriate at different size buildings, and includes furnaces, rooftop units, and boilers. Boilers have the largest potential for energy savings of all the measures analyzed. Improved controls include programmable thermostat and energy management systems.

For commercial new construction, we estimate that up to 50% savings can be reached cost-effectively (NREL 2008).

Figure 17. Commercial Natural Gas Efficiency Potential in 2025 by End-Use in Pennsylvania

Total: 48 Trillion Btu
29% of Projected Natural Gas Use in 2025



Fuel Oil

To examine the potential for energy efficiency resources in Pennsylvania's commercial sector, a scenario of 10 cost-effective measures for fuel oil savings are adopted during the 18-year period from 2008 to 2025. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy (CCE) is less than $2.50 per gallon saved, which is the average retail fuel oil price in Pennsylvania over the study time period (Reference Price Forecast). For the sum of all measures, the estimated levelized cost is 98 cents per gallon saved (Table 11). See Appendix B for a detailed methodology and specific efficiency opportunities and cost-effectiveness for residential buildings (see Table B-5).

Table 11. Commercial Fuel Oil Efficiency Potential and Costs by End-Use

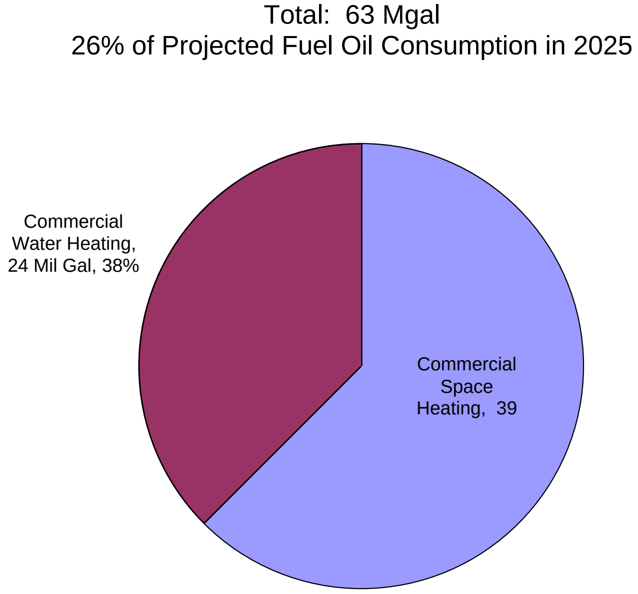
End-Use	Savings (Mgal)	Savings over Reference Case (%)	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/gal)
Space Heating	39	16.5%	62%	$0.97
Water Heating	24	9.9%	38%	$1.01
Total Fuel Oil	63	26.4%	100%	$0.98

Commercial buildings can reduce fuel oil consumption by about 26% through the adoption of a variety of efficiency measures. The economic potential for efficiency resources in the residential sector can reduce fuel oil use by 63 Mgal through the period 2008-2025.

In the commercial sector, fuel oil savings from efficiency resources can be realized through improved building shell performance (e.g., roof insulation and new windows) and more efficient heating equipment. These load reduction measures account for 62% of potential savings.

Measures to reduce hot water loads (e.g., pipe insulation and pump controllers) can yield additional savings for households with electric water heaters. The use of more efficient water heaters further reduces electricity used for water heating. As a fraction of total savings potential in the commercial sector water heating constitutes 38% of potential savings (Figure 18).

Figure 18. Commercial Fuel Oil Efficiency Potential in 2025 by End-Use in Pennsylvania



Industrial

The industrial sector is the most diverse economic sector, encompassing agriculture, mining, construction and manufacturing. Because energy use and efficiency opportunities vary by individual industry—if not individual facility, it is important to develop a disaggregated forecast of industrial electricity and natural gas consumption. Unfortunately, this energy use data is not available at the state level, so ACEEE has developed a method to use state-level economic data to estimate disaggregated electricity and natural gas use. This study drew upon national industry data to develop a disaggregated forecast of economic activity for the sector. We then applied energy intensities derived from industry group electricity consumption data reported and the value of shipments data to characterize each sub-sector's share of the industrial sector electricity consumption and projected the energy use through 2025. Figure 19 shows the largest electricity consuming industries in Pennsylvania in 2008 and 2025.

Due to changes in economic activity and energy intensity as discussed in Appendix B, we see a significant intra-sectoral shift in electricity consumption. As the figure shows, a significant increase is projected in the share of industrial electricity use by chemical and electronic manufacturing (growing from 26% to 35%), with corresponding reductions in other industrial sub-sectors, especially primary metal manufacturing (shrinking from 25% to 20%). Also of note is petroleum & coal products manufacturing, which more than double from 3% to 7%. These intra-sectoral shifts are important because they identify where new investments are being made and where energy efficiency opportunities are concentrated.

Figure 19. Estimated Electricity Consumption for the Largest Consuming Industries in Pennsylvania in 2008 and 2025

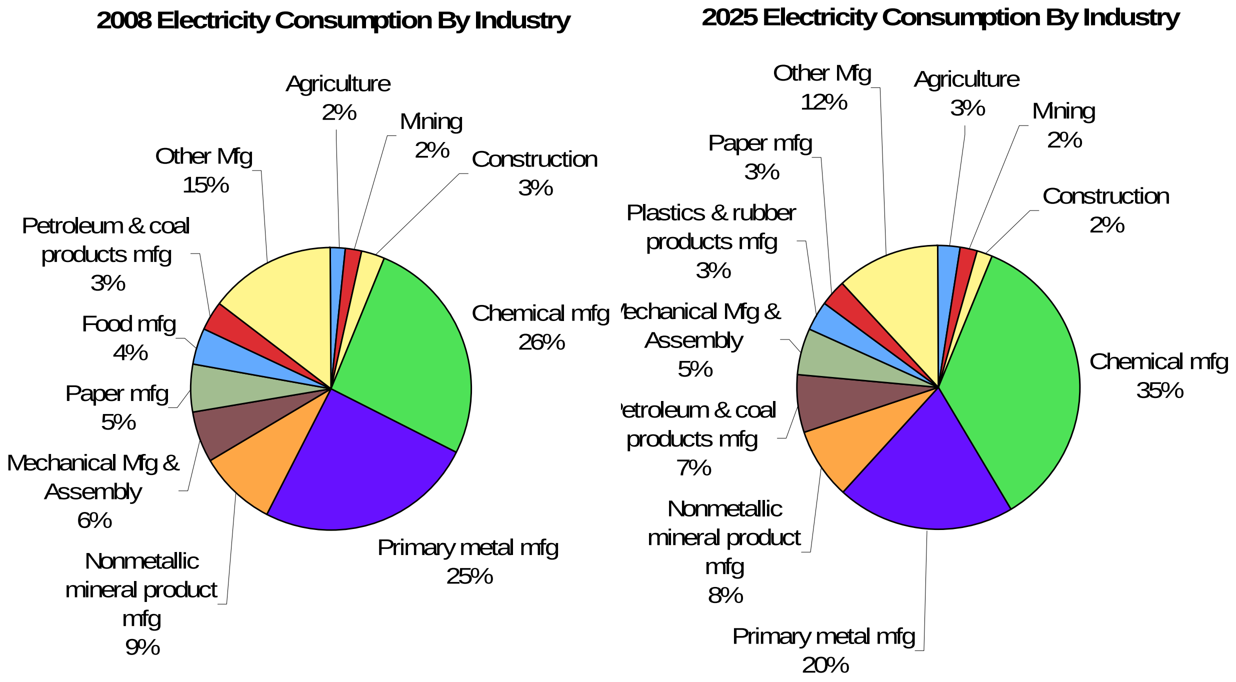
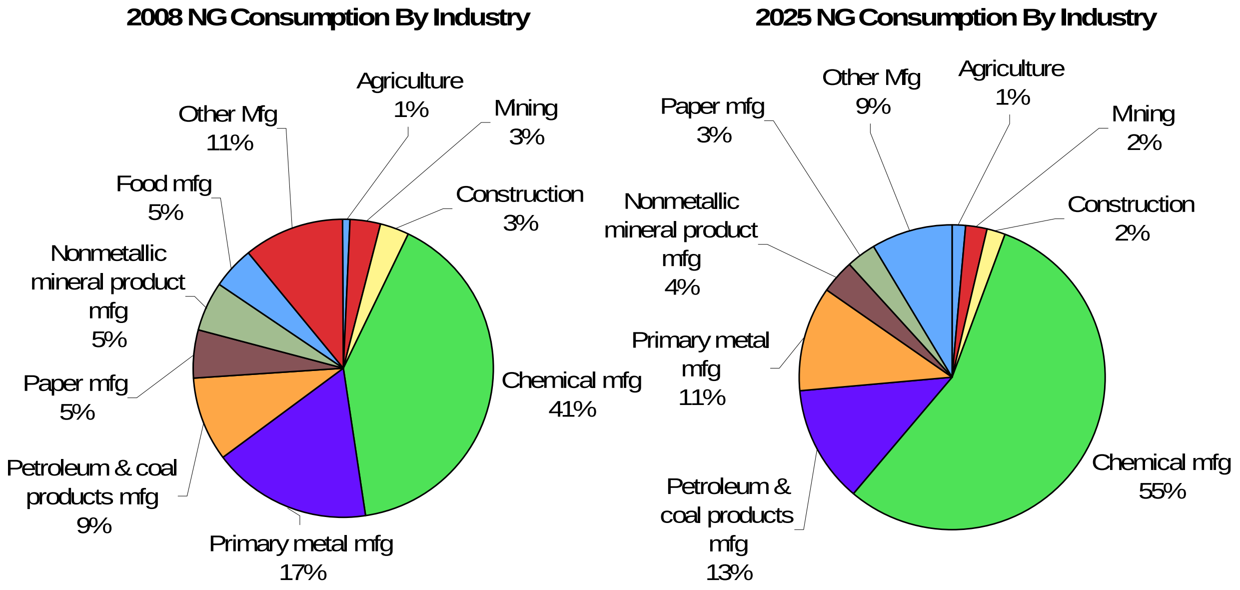


Figure 20 shows the largest natural gas consuming industries in Pennsylvania in 2008 and 2025.

Figure 20. Estimated Natural Gas Consumption for the Largest Consuming Industries in Pennsylvania in 2008 and 2025



Similar changes in economic activity and energy intensity cause significant intra-sectoral shifts in natural gas consumption. As with electricity, the chemical manufacturing sector will grow significantly, from 41% to 55% of total industrial natural gas use, and primary metal manufacturing will shrink from 17% to 11%. Petroleum & coal products manufacturing display modest growth, increasing from 9% to 13%. These intra-sectoral shifts are important because they identify where new investments are being made and where energy efficiency opportunities are concentrated.

Electricity

We examined 18 electricity saving measures, 10 of which were cost effective considering Pennsylvania's average industrial electric rate of $0.069 /kWh. These measures were applied to an industry specific end-use electricity breakdown. Table 12 shows results for industrial energy efficiency potential by 2025.

Table 12. Industrial Electricity Efficiency Potential and Costs by Measure

Measures	Savings Potential in 2025 (GWh)	Savings Potential in 2025 (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/kWh)
Sensors & Controls	237	0.4%	0%	$0.014
EIS	67	0.1%	0%	$0.061
Duct/Pipe insulation	1,587	2.8%	3%	$0.052
Electric Supply	1,710	3.0%	3%	$0.010
Lighting	550	1.0%	1%	$0.020
Motors	2,240	3.9%	4%	$0.027
Compressed Air	1,030	1.8%	2%	$0.000
Pumps	1,523	2.7%	3%	$0.008
Fans	231	0.4%	0%	$0.024
Refrigeration	123	0.2%	0%	$0.003
Total	9,297	16%	100%	$0.021

This analysis found economic savings from these cross-cutting measures of 9,297 million kWh or 16% of industrial electricity use in 2025 at a levelized cost of about $0.02 per kWh saved. This analysis did not consider process-specific efficiency measures that would be applied at the individual site level because available time, funding, and data did not allow this level of analysis. However, based on experience from site assessments by the U.S. Department of Energy and other entities, we would anticipate an additional economic savings of 5–10%, primarily at large energy-intensive manufacturing facilities. The overall economic industrial efficiency resource opportunity is on the order of 21–26%. Therefore, the total economic potential for electricity savings in the industrial sector in 2025 would be about 12,824 GWh.

Natural Gas

We examined 36 natural gas saving measures, 35 of which were cost effective considering Pennsylvania's average industrial natural gas rate of $11.72 /MMBtu. These measures were applied to an industry specific end-use electricity breakdown. Table 13 shows summarized results for industrial energy efficiency potential by 2025. A full measure list can be found in Appendix B.

Table 13. Industrial Natural Gas Efficiency Potential and Costs by Measure

Measures	Savings Potential in 2025 (BBtu)	Savings Potential in 2025 (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/MMBtu)
Load control	2,809	1.3%	8%	$0.13
Improved insulation	5,618	2.6%	15%	$0.63
Steam trap maintenance	4,389	2.0%	12%	$0.45
Automatic steam trap monitoring	1,756	0.8%	5%	$0.33
Other Boiler measures	5,255	2.4%	14%	$0.15
HVAC Measures	622	0.3%	2%	$4.47
Process Controls & Management	3,679	1.7%	10%	$0.51
Efficient burners	2,929	1.4%	8%	$1.85
Process integration	4,346	2.0%	12%	$8.39
Other Process Heat measures	5,359	2.5%	15%	$3.41
Total	36,759	17%	100%	$1.96

This analysis found economic savings from these cross-cutting measures of 36,759 billion Btu, or 17% of industrial natural gas use in 2025 at a levelized cost of about $1.96 per million Btu saved. Once again, this analysis did not consider process-specific efficiency measures that would be applied at the individual site level. As with electricity, we would anticipate an additional economic savings of 5–10%, primarily at large energy-intensive manufacturing facilities. The overall economic industrial efficiency resource opportunity is on the order of 22–27%. Therefore, the total economic potential for natural gas savings in the industrial sector in 2025 would be about 52,660 Btu.

Combined Heat and Power

Combined heat and power (CHP) provides substantial increases in overall fuel efficiency by generating both electric and thermal power from a single fuel source. This co-generation process bypasses most of the thermal losses inherent in traditional thermal electricity generation, where half to two-thirds of fuel input is rejected as waste heat. By combining heat and power in a single process, CHP systems can produce efficiencies of 70% or greater (Elliott and Spurr 1998).

For this report, Energy and Environmental Analysis (EEA), a division of ICF International, undertook an assessment of the cost-effective potential for CHP in Pennsylvania. EEA identified about 11,000 MW from CHP plants currently operating in the state.[16] Additional cost-effective potential was estimated by assessing the electricity end-uses at existing industrial, commercial, and institutional sites across the Commonwealth and also considering sites that will likely be built in the future. These facilities would replace a thermal system (usually a boiler) with a CHP system that also produces power and that is primarily intended to replace purchased power that would otherwise be required at the site. Detailed information from this analysis is provided in Appendix E.

An additional application of CHP considered by this analysis is in the production of power and cooling though the use of thermally activated technologies such as absorption refrigeration. This application has the benefit of producing electricity to satisfy onsite power requirements and displacing electrically generated cooling, which reduces demand for electricity from the grid, particularly at periods of peak demand (see Elliott and Spurr 1998).

Three levels of potential for CHP were assessed (see Appendix E for detailed results):

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[16] This estimate excludes "qualifying facilities" under *Public Utility Regulatory Policy Act 1978*, Sec. 210. For a expanded discussion, see Elliott and Spurr (1998).

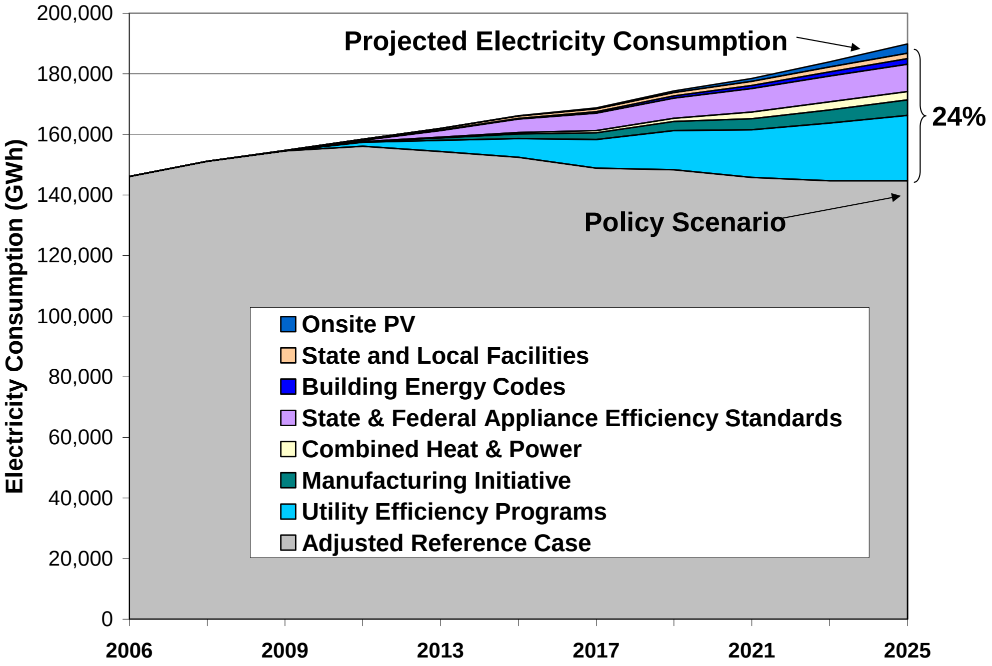
- *Technical potential* represents the total capacity potential from existing and new facilities that are likely to have the appropriate physical electric and thermal load characteristics that would support a CHP system with high levels of thermal utilization during business operating hours.
- *Economic potential*, as discussed below, reflects the share of the technical potential capacity (and associated number of customers) that would consider the CHP investment economically acceptable according to a procedure that is described in more detail in Appendix E.
- *Cumulative market penetration* represents an estimate of CHP capacity that will actually enter the market between 2008 and 2025. This value discounts the economic potential to reflect non-economic screening factors and the rate that CHP is likely to actually enter the market. This potential assumes a financial incentive for the installation of CHP systems and is described in the energy efficiency policy scenarios, which are shown in the next section of the report.

The analysis identified about 2,300 MW of economic potential for CHP, beyond what is currently installed, assuming estimated electricity and natural gas price forecasts. Assuming a scenario in which customers installing CHP systems are provided a $500 incentive per MW installed, the economic potential increases to about 3,900 MW. Policies and incentives provide the framework upon which customers in Pennsylvania can tap into this larger CHP resource potential. See the policy analysis for estimates of the market penetration impacts from such an incentive.

ENERGY EFFICIENCY POLICY ANALYSIS

In this section we outline a suite of energy efficiency policy opportunities, as summarized in the Text Box on the following page (Table 14), and estimate the resulting energy savings, costs, and consumer energy bill ($) savings. The goal of this suite of policies is to tap into the available energy efficiency resource potential described above. First, we discuss the policy recommendations in the context of current policies in Pennsylvania. Then we estimate the impacts of these policies on statewide electricity, peak demand, natural gas, and fuel oil consumption. We estimate that the following policies have the potential to meet 25% of the state's electricity needs in 2025 (see Figure 21), 15% of the natural gas needs, and about 11% of fuel oil needs. We then assess the impacts of these state-level policies on the greater Philadelphia and Pittsburgh metro regions, along with extension of certain policies and programs to municipalities in these regions. Finally, we report the estimated investments and program costs of this suite of policies for the Commonwealth.

Figure 21. Share of Electricity Met by Energy Efficiency and Onsite Solar in Policy Scenario



Discussion of Policy Analysis and Recommendations

Appliance Efficiency Standards – Federal and State

Lighting and appliance efficiency standards, first authorized by Congress in the 1970s and legislated again in 1987, 1992, 2005 and 2007, have become a core energy policy for the United States, setting performance targets for dozens of common household and business products and systems. In December 2007, Congress passed the Energy Independence and Security Act (EISA), which established lighting and appliance standards for several new products and directed DOE to set standards for a number of additional products in the next few years. Because energy savings impacts from these standards are not accounted for in the reference case, we include federal efficiency standards as part of the suite of policy suggestions for this analysis. In Pennsylvania, we estimate savings from these standards to result in about 4% electricity savings and 1.6% gas savings in 2025 compared to a reference case. The Commonwealth should continue to support strong federal appliance standards through rulemakings by DOE and enacted through legislation.

Table 14. Text Box: Summary of Energy Efficiency Policy Suite for Pennsylvania

Appliance and Equipment Efficiency Standards. Push for strong federal efficiency standards and encourage additional state-level opportunities for appliance efficiency standards.

Building Energy Codes and Enforcement. Adopt the full set of 2009 IECC provisions. Actively support and adopt stringent codes for new buildings at least on par with recommendations made at the federal level: 30% beyond IECC by 2012; and 50% beyond IECC by 2020. Expand code official and builder training efforts to increase code enforcement and launch regular assessments of code compliance.

Energy Efficiency Resource Standard (EERS) for Electricity and Natural Gas Distributors. Extend and increase electricity savings targets in Act 129 to reach 1.25% incremental annual savings per year by 2015, 1.5% by 2017, and 1.75% by 2022. Also, establish EERS targets for natural gas distributors of 0.25% per year and ramping up to 1% per year by 2018. Support a manufacturing Initiative to enable energy savings in the industrial sector and promote increased penetration of CHP systems to help meet EERS targets. Finally, review enabling policies to encourage utilities to go beyond the required energy efficiency targets, such as creation of a “loading order” that requires utilities to first procure all cost-effective energy efficiency resources before procuring other resources.

Industrial Initiative. Establish a government/utility/industrial collaborative to address the three key barriers to expanded industrial energy efficiency: the need for assessments that identify energy efficiency opportunities; access to industry-specific expertise; and the need for an expansion of the trained manufacturing workforce with energy efficiency experience. The initiative could start by expanding efforts at the current Industrial Assessment Center (IAC) at Lehigh University, and eventually opening another center in western Pennsylvania. Expanding beyond the IAC model, these centers would partner with local community colleges and trade schools to bring their students into the larger network centered on the local Center of Excellence.

Combined Heat & Power: Financial Incentives and Regulatory Policies. Leverage federal tax credits for Combined Heat & Power (CHP) with state financial incentives to incentivize customer installation of CHP systems. Support CHP as eligible for state EERS targets; establish output-based emissions regulations; and review standby tariffs for CHP systems.

Demand Response. Expand demand response (DR) capabilities by: (1) integrating and cross-marketing energy efficiency and demand response programs; (2) considering residential and small business AC direct load control programs; (3) educating customers on demand response offerings and benefits; (4) increasing clarity and coordination between Federal and State agencies and programs; and (5) expanding customer participation in TOU pricing and day-ahead hourly pricing to increase overall market efficiency.

On-Site Solar Strategies. Continue a sustained effort to provide financial incentives and offer financing to reduce high upfront solar system costs. Ensure equipment availability through active recruitment and incentives for manufacturers of solar panels and system components throughout PA and by linking economic development and renewable energy public policy goals. Support quality installation infrastructure through workforce development, installer job training and certification, and quality assurance programs. Develop program capabilities and capacity to keep up with application flow and inspections.

Consumer Financial Incentives. Expand existing energy efficiency financial incentive programs for residential consumers and small businesses, now offered by the Pennsylvania Department of Environmental Protection (DEP), which include a loan program in conjunction with the Keystone HELP loan program and a customer rebate program. As prospective long-term EERS targets for electric and natural gas utilities would encourage efficiency for electric and gas customers, gear this consumer financial program to target fuel oil and propane users.

State and Local Facilities: Energy Service Performance Contracting. Expand existing ESPC program to reach 100% of both state and local facilities with energy efficiency services by 2025. Continue to identify streamlined processes and modifications to existing programs to best achieve energy services for public facilities.

Low-Income Energy Efficiency Programs. Expand and increase the effectiveness of low-income energy efficiency services through the Weatherization Assistance Program (WAP) and electric and natural gas companies’ Low Income Usage Reduction Program (LIURP). Establish strong coordination among LIURP, WAP, and DEP financial incentives program in order to best serve low- and moderate-income households.

Workforce Development. Establish an inter-agency stakeholder group to coordinate workforce development activities, bringing together entities such as the PUC, the Department of Community and Economic Development (DCED), DEP, Labor and Industry, the Pennsylvania Economic Development Association (PEDA), and municipal organizations.

Public Education Campaign To kick-start near term initiatives, such as energy efficiency financial programs offered by DEP and federal stimulus efficiency initiatives, establish a statewide public education campaign to increase consumer awareness.

Individual states have played and continue to play an important role in advancing standards for the nation. In the 1980s, states' initiatives in developing standards in the face of federal inaction led to the landmark National Appliance Energy Conservation Act of 1987 (NAECA). Since then, state enactment of standards on products not covered by federal law has led to many new federal standards. Current opportunities for state appliance efficiency standards include: furnace fans; fluorescent lighting fixtures; DVD players; compact audio equipment; portable electric spas; water dispensers; hot food holding cabinets, TVs; and portable lighting fixtures. We estimate that savings from these new standards, effective 2010 (except 2013 for furnace fans), would meet 1.2% of forecasted electricity consumption in the Commonwealth in 2025.

Building Energy Codes and Enforcement

There are currently 5.5 million residences in Pennsylvania and it is expected that 22,000 new houses, including single-family and multifamily, will be built per year in the next few years, climbing to 30,000 houses per year by 2025 (Economy.com 2008). Although this is a downturn from the recent 45,000 homes built in 2006, it still represents a significant opportunity to "lock-in" energy savings in Pennsylvania's built environment. Construction of new, inefficient buildings is often referred to as the "lost opportunity" for energy savings because of buildings' long lifetimes and the difficult and expensive nature of retrofits. Building energy codes, which were first enacted by states in the 1970s and early 1980s, require incorporation of energy efficiency measures in new residential and commercial buildings at the time of construction and therefore begin to save energy immediately and throughout the lifetime of the buildings. Energy codes typically specify requirements for the building shell and windows, minimum air leakage, and minimum efficiency for heating and cooling equipment.

Today, most states have adopted some form of a national model energy code called the International Energy Conservation Code (IECC) for residential buildings with a reference to an ASHRAE code for commercial buildings. In Pennsylvania, recent building energy code upgrades have increased the efficiency requirements of new buildings, including in 2004 when the International Code Council building energy code went into effect. Relative to the previous code, homes built to the new code were approximately 30% more efficient (Fortney & Burnett 2000). And in 2007, Pennsylvania adopted the 2006 International Energy Conservation Code (IECC) for residential buildings and with reference to ASHRAE 90.1-2004 for commercial buildings. Pennsylvania is committed to adopting the IECC, IRC Chapter 11, and Pennsylvania's Alternative Residential Energy Provisions (PA-Alt) as options for compliance with the state energy code as they are updated every three years (Turns and Fortney 2007).

Stringent energy codes must also be complemented with strong enforcement and high compliance in order to be effective. When Pennsylvania updated its residential building energy code in 2004, most municipalities opted to take the responsibility of enforcement, though prior to this relatively few municipalities were equipped to perform this task (Turns 2008). Training for code officials in the state as well as design professionals and building contractors is crucial to ensure high quality inspections and code compliance. The Pennsylvania Construction Codes Academy (PCCA) is the lead organization for the Commonwealth in charge of code official training, and has administered this effort for residential and commercial code enforcement training through the Pennsylvania Housing Research Center (PHRC). There are needs for updating the existing training programs, particularly related to a building's thermal envelope with an emphasis on mechanical systems and lighting, and expansion into new programs for builders, code officials, and HVAC contractors, including training on proper duct installation (Turns 2008). Also, RES*check* software, a commonly used compliance option within the IECC, is likely to become obsolete due to the removal of equipment performance tradeoffs in the upcoming 2009 IECC. In addition, the PA-Alt will be modified to reflect changes in the IECC, and federal equipment standards, as they occur. These changes will create an additional need for training. The current downturn in new building construction provides a unique window of opportunity to invest heavily in code official training efforts and to deal with these current challenges to code compliance.

In addition to training, building code compliance studies are another important tool to enable an effective building energy code policy. In Massachusetts, for example, compliance surveys have been conducted by taking a random sampling of homes, simulating energy consumption using computer models, and then following-up with a field survey to compare model simulations to real-world energy consumption patterns.

In this energy efficiency policy scenario, we assume the Commonwealth updates its residential and commercial building codes according to the 2009, 2012, 2015, and 2018 IECC, which become effective about 2 years after the code is adopted by ICC (effective January 1st of the year following publication by ICC). The estimated new code levels result in 15% and 30% energy savings relative to the 2006 IECC for the 2009 and 2012 codes, respectively, which correspond to the estimated savings from the recently adopted 2009 IECC (about 15%) and the level of savings pursued by the Energy Efficient Codes Coalition's (EECC) "30% Solution[17]." The 2018 IECC is estimated to result in 50% energy savings and corresponds to the level of savings targeted by the Obama administration and goals set in federal legislation, EISA 2007 (50% beyond code). Pennsylvania should adopt the full IECC 2009 provisions and actively support meeting the 30% goal by at least the IECC 2012.

This analysis also assumes that the Commonwealth expands code official training and compliance surveys in order to support enhanced enforcement and compliance of the codes. We assume that code official training, compliance surveys, and other efforts enable enforcement levels to start at 70% at the time of adoption of a new code, ramp up to 80% in the second year, 90% in the third year and later. We estimate that these efforts combined can allow buildings energy codes to meet about 1% of the state's electricity consumption in 2025 and 1.5% of natural gas consumption. This analysis assumes current projections in building construction in Pennsylvania compliance efforts, as of fall 2008 (Economy.com 2008), though increases in these forecasts would raise the potential energy savings from buildings energy codes.

Energy Efficiency Resource Standard (EERS) for Electricity and Natural Gas Distributors

In October 2008, Governor Rendell signed Act 129, which requires that Electric Distribution Companies in Pennsylvania meet 1% electricity savings by 2011 and a total annual savings of 3% by 2013, as a percent of expected electricity consumption during the year June 2009 – May 2010. This quantitative, binding energy savings target is called an energy efficiency resource standard (EERS), similar models of which have been adopted in 19 states or are currently pending in 3 additional states (ACEEE 2009). An EERS is similar in concept to a Renewable Portfolio Standard (RPS), such as Pennsylvania's Alternative Energy Portfolio Standard (AEPS), which requires that utilities meet a certain percent of generation needs from qualified renewable energy technologies. An EERS, however, requires that measured and verified energy savings offset a certain percent of electricity or natural gas needs. In our suite of suggested policies we include an EERS for both electricity and natural gas distributors.

Electricity

In this energy efficiency policy scenario, we assume that electric distribution utilities meet the required total annual savings targets of 1% in 2011 and 3% in 2013 from its 5-year programs filed in 2009, and assume that efficiency requirements are extended to 2025. We assume that utilities then file new 5-year programs in 2014, which achieve incremental annual savings of 1.25% by 2015, growing to 1.5% per year by 2017, and 1.75% by 2022, with each target relative to prior-year sales. We adjust the electricity reference case sales forecast for each of these benchmark years based on assumed total annual savings from meeting the EERS in previous years and estimated savings from appliance standards. By 2025, utility efficiency programs are meeting about 16% of the projected electricity needs of the state.

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[17] See http://www.thirtypercentsolution.org/modules/smartcontent/page.php?pageid=5.

Some states, such as Vermont, are achieving electricity incremental annual savings from efficiency programs equivalent to about 2% of the state's electricity sales. It took Efficiency Vermont, which is the state's provider of electric energy efficiency services, about seven years to ramp up to this level of savings. Achieving this level of savings in Pennsylvania will be possible, and policy makers should revisit the efficiency targets as appropriate to consider annual savings targets of 2%.

The current EERS in Pennsylvania covers the major investor-owned utilities in the Commonwealth, which account for 97% of electricity sales in the state, however in this efficiency policy scenario we assume that both municipal utilities and cooperatives meet the same targets. As an alternative policy option, a voluntary commitment to these, or lower, target levels can be established for cooperatives and municipalities with some inducement.

Natural Gas

In addition to savings targets for electric distribution utilities, several states have set targets for natural gas distribution companies, of which there are sixteen in Pennsylvania. Leading natural gas efficiency programs in the nation are achieving 0.5% to 1% incremental annual natural gas savings per year from efficiency programs after several few years of running programs. In this policy scenario for Pennsylvania, we assume that savings targets are established for natural gas companies to achieve incremental annual savings of 0.25% in 2010, ramping up to 0.5% in 2013, 0.75% in 2016, and 1% in 2018, which continues per year through 2025.

Program Models

There are numerous best practice models for energy efficiency programs from around the U.S. These program types and specific program examples, which cover each major customer class, are highlighted in the Text Box on the following page (see Table 15). The cost-effective resource potential for energy efficiency in Pennsylvania, described earlier in the report, finds that there is a significant untapped potential for energy efficiency in the residential, commercial, and industrial sectors, suggesting that all sectors must be targeted in order to draw on the existing resource potential (see Table 3).

Energy efficiency programs will be administered by utilities throughout Pennsylvania, though some statewide coordination among utility service territories could benefit program effectiveness, particularly education. A residential home retrofit program, for example, can be modeled according to a standard Home Performance with ENERGY STAR program. Certain program criteria, including levels of incentives and eligibility thresholds of equipment programs, particularly for residential and small commercial programs, may be most effective as standard criteria among utility service territories. Such standardization makes it easier for trade allies, such as retailers and contractors, who may operate in several service territories, and also permits joint marketing, which creates economies of scale to reduce costs and bolster participation. The effectiveness of this approach depends on many factors and there may be reason to deviate if there is strong justification. Connecticut, California and Massachusetts are examples of states that have largely standardized programs, even though there are multiple utilities.

Additionally, we suggest that the two policies discussed next, including an industrial initiative and CHP financial incentives and regulatory measures, be developed as a statewide framework and be allowed to contribute toward meeting the electricity and natural gas EERS targets.

Table 15. Text Box: Examples of Energy Efficiency Programs

While an EERS target is independent of specific energy efficiency program requirements, there are many program designs that have proven successful over the past three decades. We present several of these program types below, along with specific examples of successful implementations that are drawn from ACEEE's report *Compendium of Champions: Chronicling Exemplary Energy Efficiency Programs from across the U.S.* (York, Kushler, and Witte 2008).

Residential Retrofit Programs: With an emphasis on large scale systematic retrofits, Residential Retrofit Programs are designed to reduce electric and natural gas consumption and peak-time demand of residential buildings. Financial incentives, low-interest financing, and training are offered to residents and customers interested in assessing and improving their energy efficiency. From weatherization and duct sealing to installation of new technologies, proponents of Residential Retrofit Programs direct their efforts both to buildings with the highest energy usage and constituents with the greatest financial need. Since its inception in 1993, Vermont Gas Systems, Inc.'s *HomeBase Retrofit Program*, for example, has contributed to over 77,000 Mcf of natural gas savings. *Home Performance with ENERGY STAR* is a national model from the U.S. EPA and U.S. DOE that offers a comprehensive, whole-house approach to improving energy efficiency and certifies contractors for local- or state-sponsored programs.

Residential New Homes Programs: Provide incentives to builders who construct energy-efficient homes that achieve long-term, cost-effective energy savings. By addressing efficiency during the construction of homes and apartments, builders are able to maximize the financial and environmental benefits of efficient insulation, windows, air ducts, and appliances. Furthermore, ENERGY STAR certification provides developers with additional marketing strategies to attract buyers and renters. Some Residential New Homes programs also offer assistance to builders in developing efficiency objectives, and to potential buyers in locating efficient homes. With 100 participating residential builders and over 2,300 homes built to date, Rocky Mountain Power's *ENERGY STAR New Homes Program* saved 3.4 GWh of electricity during 2006.

Residential Mechanical Systems Programs: Provide rebates and other financial incentives to contractors trained to properly install and service high-efficiency air conditioning, heat pumps, and geothermal heat-pump technologies. In addition to encouraging the purchase of energy-efficient appliances, these programs help to verify that existing equipment is appropriately installed and tuned in accordance with manufacturers' specifications, in order to optimize energy savings. Long Island Power Authority's *Cool Homes* Program has helped to introduce approximately 40,000 high-efficiency central cooling systems into the market, creating 29 GWh of annual electricity savings in 2006.

Residential Lighting and Appliances: Headed by utility companies and energy nonprofits alike, Residential Lighting and Appliances Programs advocate the adoption of ENERGY STAR light bulbs, light fixtures, and home appliances through the use of rebates, marketing campaigns, advertising, community outreach, and retailer education. Lighting programs have focused on establishing and maintaining a customer base for compact fluorescent bulbs, in addition to fostering relationships between manufacturers and retailers in order to lower costs to the consumer. Appliance programs have sought to educate consumers on the long-term benefits of replacing aging, inefficient refrigerators, freezers, air conditioning units, and other large appliances with ENERGY STAR models, while providing an incentive to upgrade older models through rebates offered both for recycling old units and purchasing new ones. By selling 1.3 million CFLs during 2006 through its *ENERGY STAR Residential Lighting Program*, Arizona Public Service anticipates saving a total of 360 GWh of electricity during the lifetime of the light bulbs. Additionally, the *California Statewide Appliance Recycling Program* recycled 46,829 aging appliance units in 2007, a measure that saved 33.3 GWh of electricity in 2006.

Low-Income Programs: Seek to educate and assist qualifying participants in acquiring appropriate home weatherization, energy-efficient lighting and appliances, and other efficiency improvements. By helping limited income households increase their energy efficiency and reduce energy consumption, these programs in turn minimize long-term energy costs to customers. Through its *Appliance Management Program and Low-Income Services*, National Grid has reached over 40,000 customers, creating 42 GWh of annual energy savings.

Commercial/Industrial Lighting Programs: Provide recommendations and incentives to businesses to increase lighting efficiency. Aiming to expedite the adoption of new technologies and decrease end-user's energy costs, the programs focus on marketing the most advanced lighting products and encourage greater efficiency in system design and layout. Xcel Energy's *Lighting Efficiency* program reached 4,346 participants, saving a total of 273 GWh during the years 2002-2006.

(Continued from previous page)

***Commercial/Industrial Motor and HVAC Replacement Programs*:** Encourage the marketing and adoption of higher efficiency motors and HVAC equipment by offering rebates to distributors and end-users of qualifying equipment. Through monetary incentives and energy efficiency education, program advocates are shifting market tendencies away from a focus on initial equipment cost and toward an environment where lifecycle cost is increasingly considered by consumers. During 2006, Pacific Gas & Electric's *Motor and HVAC Distributor Program* saved a total of 16.55 GWh of electricity by offering $3.9 million in rebates.

Commercial/Industrial Retrofit Programs: With programs ranging from energy efficiency audits to financial assistance to even providing detailed engineering installation plans, Commercial/Industrial Retrofit Programs are designed to help implement cost-effective energy efficiency measures during new construction, expansion, renovation, and retrofit projects in commercial buildings. Programs focus on long-term energy management, peak load reduction, load management, technical analysis, and implementation assistance in order to give building owners and operators a better understanding of the energy related costs of, and potential savings for, their commercial buildings. Rocky Mountain Power and Pacific Power created approximately 100 GWh of gross electricity savings in Washington and Utah with their *Energy FinAnswer and FinAnswer Express* programs.

Commercial/Industrial New Construction Programs: Focus on training, educating, and providing financial incentives for architects, engineers, and building consultants to implement energy saving measures and technologies. By offering both prescribed and customizable incentive packages, these programs are able to influence a wide range of projects, which have in turn had the effect of raising the standards for energy efficiency in normal building practices. With its four distinct, yet combinable project "tracks," Energy Trust of Oregon, Inc.'s *Business Energy Solutions: New Buildings* program offers qualifying projects incentives of up to $465,000 each, which saved approximately 46.8 GWh of electricity and 1.2 million therms of natural gas through the end of 2007.

Enabling Policies

Rhode Island, Massachusetts, and Connecticut have all recently passed legislation creating a "loading order" for utilities in which they must use energy efficiency first. For example, in 2007 the Connecticut legislature enacted a law that places new requirements on energy efficiency, including a requirement that utilities procure all cost-effective energy efficiency as the first priority resource. Utility programs are responding accordingly and plan to achieve 1.5% savings (of total sales) each year with corresponding increased program budgets. While this policy may not alone accomplish what an EERS requires, it does serve as an enabling policy that frames efficiency as the priority rather than a second-order requirement, and requires that utilities go beyond a bare minimum savings requirement to an "all cost-effective" requirement.

In addition to state-specific enabling policies, there are regional opportunities on the horizon through the 13-state PJM Interconnection forward capacity market. In December 2008, PJM staff filed proposed tariff changes at FERC that would allow energy efficiency resources to bid into PJM's next capacity auction. If approved, it will offer new support for EE investment across the thirteen-state PJM region.

Industrial Initiative

In this energy efficiency policy scenario, ACEEE suggests and analyzes a government/utility/industrial collaborative we are calling the "Pennsylvania Efficient Industrial Initiative." The goal of the initiative is to address the three key barriers to expanded industrial energy efficiency: the need for assessments that identify energy efficiency opportunities; access to industry-specific expertise; and the need for an expansion of the trained manufacturing workforce with energy efficiency experience.

The initiative would establish Centers of Excellence in the model of the U.S. Department of Energy's Industrial Assessment Center (IAC)[18] program, where university engineering students are trained to conduct energy audits at industrial sites. The program could start by expanding

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[18] For more information on the IAC program, visit: http://iac.rutgers.edu/.

efforts at the current IAC at Lehigh University, and eventually opening another center in western Pennsylvania. Expanding beyond the IAC model, these centers would partner with local community colleges and trade schools to bring their students into the larger network centered around the local Center of Excellence. These nearby satellite centers would extend training and associated materials to trade school and community college partners, and offer the opportunity to join the audits they conduct. We also recommend working with existing manufacturing assistance programs, such as NIST's Manufacturing Extension Partnership, that may already have valuable connections.

This system would benefit three key groups: students interested in working in industrial energy management; businesses that need reliable, knowledgeable, and affordable consultation with regard to their energy usage; and the educational facilities and collaborators' outreach efforts that connect Pennsylvania's manufacturers to the wealth of knowledge and proficiency that resides in the state.

IAC program and implementation results recorded over the last 20 years show that this program could identify 10-20% electricity and natural gas savings per facility and achieve a 50% implementation rate. The number of audits per year would ramp up from 50 in the first year to 100 in the second and 200 in the third year and each following year. Based on actual IAC data and adjusting upward to account for targeting larger industries, these 200 audits could achieve cumulative savings of roughly 10% of Pennsylvania's manufacturing energy use by 2025. Because of time lag between the audit and implementation, we assume that investment and savings for each year would occur over two years, while program costs would begin in year zero. Program costs for the IAC program are about $1 for every $10 saved by industry. We factor in another $0.25 per $10 saved to account for additional education costs.

Funding for this initiative could come from a variety of sources including from utility public benefit funds or from state revenue sources. Federal legislation is currently under consideration that would expand scope and funding of the existing IAC program, including a provision for a federal match for state funding of IACs.

We recommend complementing these program offerings with economic development incentives. As in many states, Pennsylvania offers economic development incentives designed to encourage business owners to make improvements and invest in their facilities. Investments in energy efficiency count as applicable investments for many of these programs. The Pennsylvania Efficient Industrial Initiative would also help meet Pennsylvania's EERS, so these incentives could take the form of conventional utility project funding.

In addition, designating areas as Energy Improvement Districts (EIDs) are one way that some cities have steered companies toward the energy efficiency investments that ultimately positively impact their bottom lines. EIDs can take many forms, but foremost in their design is the provision of both financial and technical assistance that businesses require as they prepare to think about making investments in energy efficiency. And some EIDs pool money together from participating companies to purchase large distributed generation systems and then share the energy created by the systems, as well.

Prioritizing energy efficiency in economic development schemes makes sense because energy efficiency can help companies become more profitable and thus increase their levels of employment and investment. Furthermore, Pennsylvania is a highly business-friendly state, and has an economic development infrastructure that is strong and well connected to the business community. Using Pennsylvania's multiple economic development entities to market and/or administer energy efficiency programs is one way that Pennsylvania can get a head start on helping companies make the efficiency investments necessary to meet any EERS goals.

Combined Heat and Power Incentives

Experience over the past decade has shown that if a level playing field is created for CHP, it will thrive, as has been seen in Texas (Elliott et al. 2007b). ACEEE has identified five factors that contribute to creating a favorable market for CHP:

- Standard interconnection rules;
- CHP-friendly standby rates;
- CHP financial incentive programs;
- Output-based emissions regulations (OBR); and
- Inclusion of CHP/waste heat recovery in a state RPS or EERS.

In ACEEE's 2008 State Energy Efficiency Scorecard, Pennsylvania scored fairly well on these five policies to promote CHP. In 2006, in accordance with its Alternative Energy Portfolio Standards Act of 2004, the Commonwealth adopted interconnection standards for distributed generation, including CHP, to cover four different tiers of interconnection, up to 2 MW in size. Also, recently enacted Act 129 of 2008 establishes standardized fees and streamlined the application process for customer-sited distributed generation.

There are several areas in which state-level agencies could work to encourage greater CHP deployment:

- *Incentives*—The federal financial rescue plan of October 2008, titled the *Economic Stabilization Act of 2008*, authorized the expansion of the Investment Tax Credit to include investments in CHP. It is a 10% tax credit against the cost of installing CHP systems (for the first 15 MW) for systems up to 50 MW in size. Additional national incentives for CHP may be in the works. The *2007 Energy Independence and Security Act*'s Section 451 authorized additional funding and support for waste-heat recovery projects, which are an important subset of clean distributed generation. Though this authorization has not been funded, anecdotal evidence suggests it will garner attention in 2009.

  Pennsylvania should encourage the use of these incentives in order to increase deployment of CHP. Institutional facilities, such as hospitals and universities, are particularly good candidates for installation of CHP facilities. In addition, the state can develop incentives, such as favorable property tax treatment, which are allocated to the portion of the property covered by a CHP system. Other states provide sales tax incentives based upon the size and output of CHP systems. These of course help reduce the overall cost of operating a CHP system and thus work to encourage deployment.

- *Output-Based Emissions Regulations*—To encourage CHP deployment, many states also develop output-based emissions regulations (OBR), as opposed to emissions regulations based upon fuel input. OBRs take into account the fact that CHP systems produce more useful energy with their fuel inputs than other systems, and so give credit to the useful thermal output produced by CHP systems. Total emissions are calculated based upon system output, as opposed to fuel input. In this way, OBRs encourage CHP deployment.

- *Include CHP in EERS*—Finally, states that wish to encourage deployment of CHP and other forms of clean distributed generation often include these technologies as eligible resources for their Renewable Portfolio Standards or EERS. Currently, CHP is included in Tier II of the state's AEPS. However, there is no required carve-out of the savings requirement for CHP, which could act in concert with financial incentives and OBR to encourage the deployment of CHP.

These steps, which will lead to regulatory certainty, will reduce the effective cost of CHP projects. We project that these steps will reduce the effective cost of CHP projects by $500/kW installed. Based on the market penetration scenario of EEA's analysis, a $500/kW incentive can result in additional CHP peak demand capacity of about 500 MW by 2025, equivalent to 2,750 GWh or a 1% reduction in overall electricity consumption. CHP also represents a low cost source of efficiency reductions, particularly in the commercial sector. We thus suggest that utilities be encouraged to participate in encouraging expanded CHP, which could lead to a $1,000/kW reduction in cost through project funding participation.

Consumer Financial Incentives

Financial incentive programs for residential consumers and small businesses are now in development by the Pennsylvania Department of Environmental Protection (DEP) with $92.5 million in funding from the Alternative Energy Investment Fund and are likely to begin running in early 2009. These resources will support a loan program, in conjunction with the Keystone HELP loan program, and a rebate program to support energy efficiency to reduce energy usage for residential and small business customers.

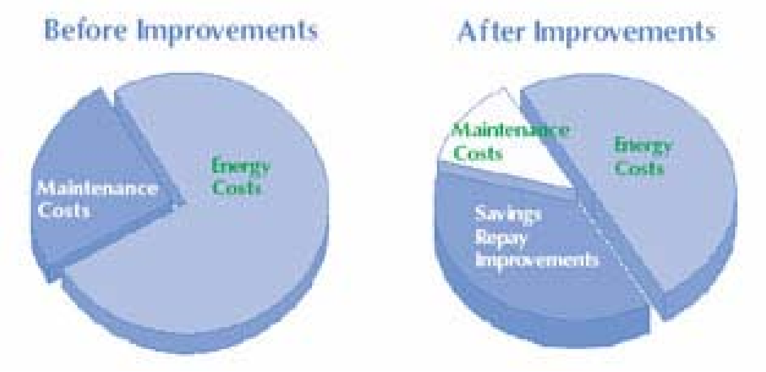
In this policy scenario, we assume that that the current level of program funding for financial incentives, which will be leveraged by additional customer investments, will achieve some energy savings for electricity, natural gas, and fuel oil customers. However, as EERS targets for electric and natural gas utilities ramp up in this policy scenario, there will be a strong need for this program to target fuel oil and propane users. Possible funding to support expansion of this program could come from another bond issue by the state, by future revenues from a federal carbon cap and trade program, or through a small tax on fuel oil.

We estimate that this expanded consumer financial program in 2015 could achieve savings of about 114 GWh (0.1% of statewide usage), 1,900 BBtu of natural gas (0.3%), and 27 million gallons of home heating fuel. In our analysis, we assume that the program continues to shift away from customers that heat with natural gas or electricity and focuses solely on customers that heat with fuel oil. By 2025 total annual savings reach 115 million gallons of oil, which reduces total consumption in the state by 10% compared to the reference case.

State and Local Facilities: Energy Savings Performance Contracting

State and local government buildings provide a unique opportunity to introduce and ramp-up energy efficiency practices: they represent about 18% of electricity consumed by commercial buildings in the state, 16% of natural gas consumption, and 25% of fuel oil consumption in the commercial buildings sector (EIA 2006b); and they allow government to "lead by example" in employing energy efficiency strategies. Energy savings performance contracting (ESPC) is one model employed by state governments to retrofit existing facilities for efficiency improvements. Under this model, state agencies hire Energy Service Companies (ESCO) to implement projects designed to improve the energy efficiency and lower maintenance costs of the facility. The ESCO guarantees the performance of its services, which are paid back through the facility's energy bill savings as shown in Figure 22 (KCC 2008; Birr 2008). This model has proven highly effective in many places both in terms of delivering energy savings and in terms of cost effectiveness (LBNL 2008).

Figure 22. Graphical Representation of How an ESPC Project Is Financed



Source: KCC (2008)

In 1998, the Governor's Green Government Council was established in Pennsylvania by executive order to introduce environmental sustainability into public buildings management and identified energy efficiency as a priority. The Pennsylvania Department of General Services (DGS), the agency responsible for Commonwealth buildings, began implementing an energy performance contracting program in 2000 to allow agencies to do ESPC for existing buildings without the requirement for up-front capital budget allocation. For the Guaranteed Energy Savings Act (GESA) program, DGS has developed model procurement and contracting documents and procedures for state agencies to use when procuring and implementing EPC projects and also pre-qualifies ESCOs, which develop, install, and finance projects over a fifteen year time period. There are currently 18 qualified ESCOs to serve these projects (DGS 2009).

Through performance contracting, at least 37 of the Commonwealth's public facilities, including office buildings (10), universities (12), correctional facilities (7), and other buildings such as health care facilities (8), have undergone energy efficiency projects (LBNL 2008), representing 19% of the state facilities market in terms of floorspace. Savings from these projects have reached about 0.1 million Btu and $18 million in lower energy bills (LBNL 2008).

In our energy efficiency policy scenario, we estimate that ESPC program requirements are established so that the remaining 80% of state public building buildings (in terms of floorspace) participate in an ESPC model by 2025 and achieve an average 20% savings per facility. The initiative should also be expanded to reach the local buildings market, which ramps up to meet 80% of the market by 2025. Both of these efforts will results in energy savings of about 1,700 GWh in 2025, meeting about 1% of the state's total electricity needs.

Workforce Development

Investments in energy efficiency are highly labor-intensive – on average, every one million dollars of revenue for the Pennsylvania construction industry, for example, a sector that is vital to efficiency projects, produces about 8 jobs. For the energy supply, or electric utility sector, however, one million dollars of revenue produces only 2.5 jobs in Pennsylvania. The public and private investments needed to drive efficiency programs and policies outlined in this analysis therefore have a strong, net positive effect on employment in the state – we estimate a net 27,000 jobs in 2025 compared to a business-as-usual scenario. Moreover, these hands-on jobs must come from within the state, and therefore cannot be out-sourced. For a more detailed discussion of this analysis, see the section on Macroeconomic Impacts: The DEEPER Model, later in the report.

Given the recent economic downturn and job losses in Pennsylvania, and energy efficiency's net positive effect on employment, efficiency policies and programs should be a core component to an economic development strategy in the Commonwealth. While job creation is a number one priority in the Commonwealth, this *demand* for employees creates the need for a qualified *supply* of local, well-trained workers. This must be done through a sustained and coordinated workforce development strategy. Investing in this human capital will both maximize the efficacy of efficiency programs and contribute to the state's economic development by creating new "green collar" jobs.

The jobs needed for energy efficiency vary – including installers, technicians, engineers, architects, evaluation professionals, building operators, etc. Given these diverse trades for various sectors and yet overlapping training needs, job training must come from a diverse set of programs and collaborative efforts. The establishment of an inter-agency stakeholder group to coordinate workforce development activities, or a “workforce council,” is therefore critical and should bring together entities such as utilities, the PUC, the Department of Community and Economic Development (DCED), Labor and Industry (L&I), the Department of Environmental Protection (DEP), the Pennsylvania Economic Development Authority (PEDA), and universities. For utilities, the dynamics of individual programs contributing to the state’s EERS requirements will be facilitated by a stakeholder group overseeing the process in general while providing the various parties a venue for exchanging and soliciting ideas. Communication within and between the programs is imperative to guarantee that individuals are obtaining the proper education to satisfy the needs of the individual market sectors as well as guaranteeing job placement once their training has been completed.

Public Education Campaign

Several new energy efficiency programs by the state DEP and utilities will be offered in Pennsylvania in the near future. Given this new breadth of program offerings to consumers, a public education effort would be beneficial to encourage both awareness of programs and actions that consumers can take on their own to save energy. An education campaign could exist through a wide array of media and calls by the Governor for energy conservation. Public education campaigns in California and elsewhere have been shown to produce lasting demand reductions. Recent efforts which provide monthly feedback to customers on their bills, comparing their usage to the average customers for example, show significant savings.

California achieved about 7% energy savings and 11% peak demand savings in 2001 following its education campaign (Global Energy Partners 2003), with savings in 2002 persisting at about one-half to two-thirds of the 2001 figure (Lutzenhiser et al. 2004). Experience in California is not unique, since other states such as New York have succeeded in achieving significant short-term reduction through public awareness efforts (Elliott, Shipley, and Brown 2003). These state efforts were driven by immediate concerns in meeting peak demand loads, for which Pennsylvania does not have the same sense of urgency, though lessons from these could still be drawn, and the campaign could be tailored to the needs of Pennsylvania. Several elements were critical to the success of those efforts:

- A consistent message and sense of urgency from a broad array of leaders including: elected officials such as the Governor, utility commissioners, and mayors of major cities; electric utilities; and media.
- Make it clear that if everyone makes modest contributions, the state as a whole will benefit.
- Provision of actionable guidance to consumers directing what specific steps they can take to contribute, such as raising their thermostats by 4 degrees when they are away from home, buying compact fluorescent lamps (CFLs), or tuning-up their air conditioners, and
- Report back to the public on the success of their efforts so they get a sense that they are making a difference.

If these elements are adhered to, significant energy savings and reductions in peak demand can be achieved at a very modest cost. One of the observations from many Californians, however, was that they did not see many lifestyle impacts from their conservation efforts. The one limitation in this policy is that these efforts may not be effectively sustained for more than 18–24 months. However, the policy can buy important time to kick-start near term initiatives and get the other longer-term efficiency policies in place.

Low-Income Programs

Addressing the needs of low-income households is crucial when implementing efficiency programs as these households spend on average a greater percentage of their income on energy than other customers. Programs like DOE's Weatherization Assistance Program (WAP) provide households with home energy efficiency and conservation services, thus enabling households to permanently reduce their energy bills and free up funds for more pressing needs. In Pennsylvania, WAP is administered statewide through the Department of Community and Economic Development, which in 2008 has a budget of about $23 million, and each county is served by a designated agency. Eligible customers are households whose income is 60% of the state median income (DCED 2008). To determine verified energy savings and program effectiveness, the WAP program should be independently evaluated.

Low-income conservation services in Pennsylvania are also available through utilities. At the time Pennsylvania opened up its electric generation and natural gas supply markets to competition, under the Electric Choice Act and subsequent Natural Gas Choice Act[19], the Public Utility Commission was directed to maintain services that help low-income customers afford electricity and natural gas. Each year, the Commonwealth's seven major electric distribution companies (EDCs) and eight major natural gas distribution companies (NGDCs) must report information to the PUC on their universal service and energy conservation programs to low-income customers[20]. In 2007, about 9% of electric customers and 16% of natural gas customers in Pennsylvania were verified as low-income according to the federal guidelines, though it is estimated that the total number of low-income customers is 18% and 21% of electric and gas customers, respectively (BCS 2008).

Among other programs and services, PA PUC mandates and has oversight of the Low Income Usage Reduction Program (LIURP), which is run by each of the major EDCs and NGDCs to help low-income residential customers reduce energy bills through energy conservation. LIURP is targeted toward low-income customers below 150% of the federal poverty level and those that are the highest energy users (annual usage of at least 6,000 kWhs and 120 Mcfs). LIURP funds are included in utility rates as part of the distribution costs passed on to all residential customers and are set for each utility every three years. LIURP spending in 2007 totaled about $21 million by electric utilities for about 21,000 customer jobs (0.4% participation) and $7.5 million by natural gas utilities for about 3,700 customer jobs. Average energy savings per customer job ranged from 7-16% (BCS 2008).

The American Recovery and Reinvestment Act (ARRA), signed into law by President Obama on February 17, 2009, provides an unprecedented opportunity for deeper savings and pilot programs for low-income consumers, e.g., Zero Energy Retrofits. President Obama's campaign platform recommended an increase in funding for WAP in order to target 1 million homes per year in the U.S., and ARRA provides $5 billion for the Weatherization Assistance Program (WAP). As Pennsylvania looks to coordinate its LIURP, WAP, and DEP financial incentives program, the Commonwealth should develop plans to enable the state to rapidly ramp up its capabilities to accept greater levels of funding.

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[19] The Natural Gas Choice and Competition Act, 66 Pa. C.S. Chapter 22, was enacted on June 22, 1999.

[20] In 2007, a low-income customer was defined as a customer whose household income was at or below 150% of the federal poverty guidelines (BCS 2008).

Energy Efficiency and Onsite Solar Policy Scenario Results

Shown in Table 16 is a summary of energy savings in 2025 that result from the energy efficiency policies described above and the solar market assessment by VEIC. In total, these policies and programs combined can meet 24% of the projected electricity needs of Pennsylvania in 2025, 15% of natural gas needs, and 11% of fuel oil needs. Peak demand impacts from efficiency efforts alone reach about 23% reductions; however, combined with demand response efforts total reductions reach about 35% (Figure 23). See Appendix C for year-by-year estimates of energy savings (for odd years only).

Table 16. Total Energy Savings in 2025 from Energy Efficiency and Onsite PV Policy Analysis

Policies and Programs	Electricity		Peak Demand		Natural Gas		Fuel Oil	
	GWh	%*	MW	%*	BBtu	%*	MilGal	%*
Federal Appliance Standards	6,900	3.7%	1,900	4.6%	9,900	1.6%	0.3	<0.1%
State Appliance Standards	2,200	1.2%	400	1%	NA	NA	NA	NA
Building Energy Codes	1,800	1.0%	400	1%	9,600	1.5%	NA	NA
Energy Efficiency Resource Standard (EERS)								
Res. Buildings Programs	11,100	6%	2,500	6%	26,700	4.2%	NA	NA
Comm. Bldgs. Programs	10,500	5.6%	2,300	5.6%	17,800	2.8%	NA	NA
Industrial Initiatives	5,100	2.7%	850	2.0%	25,436	4.0%	NA	NA
CHP Policies /Incentives	2,800	1.5%	500	1.2%	NA	NA	NA	NA
EERS - Subtotal	29,400	16%	6,100	15%	69,900	11%	NA	NA
Consumer Financial Initiatives	30	<0.1%	7	<1%	1,400	0.2%	115	10%
State and Local Facilities	1,800	1.0%	377	1%	4,500	0.7%	10	1%
Onsite PV	3,100	1.7%	NA	NA	NA	NA	NA	NA
Demand Response	NA	NA	5100	12%	NA	NA	NA	NA
Total	45,200	24%	27,200	35%	95,000	15%	125	11%

*Note: Percent (%) reductions are presented as a fraction of *projected* energy use in the reference case.

Figure 23. Share of Electricity Met by Energy Efficiency and Onsite Solar in Policy Scenario

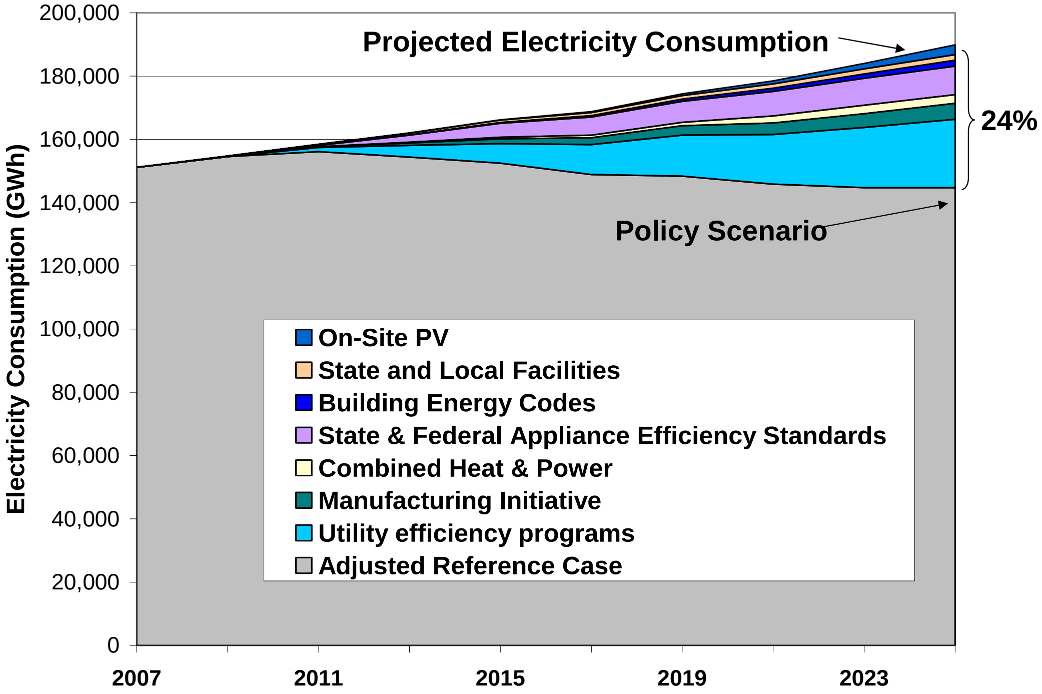


Figure 24. Share of Summer Peak Demand Met by Energy Efficiency and Demand Response

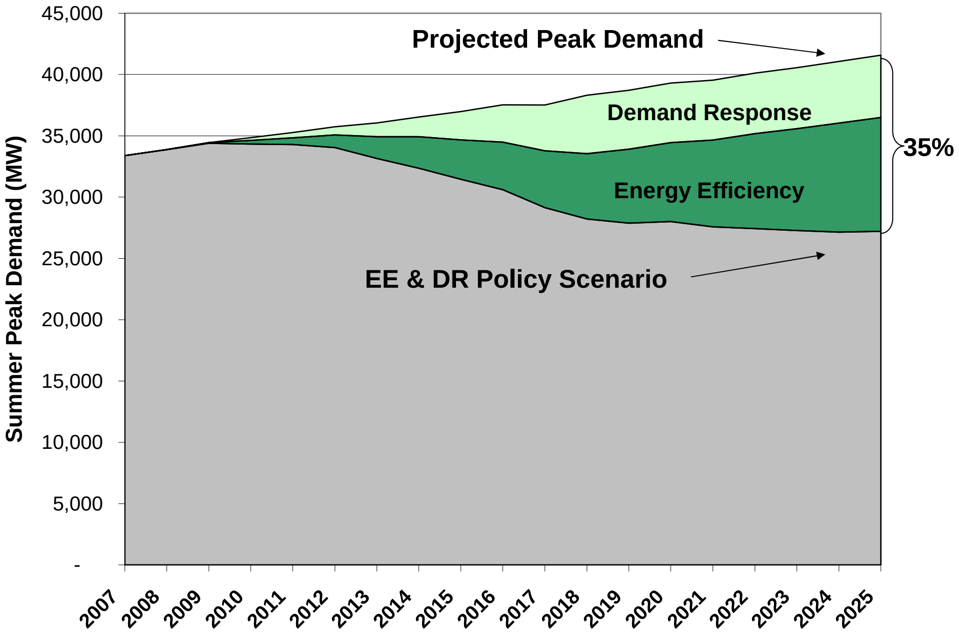
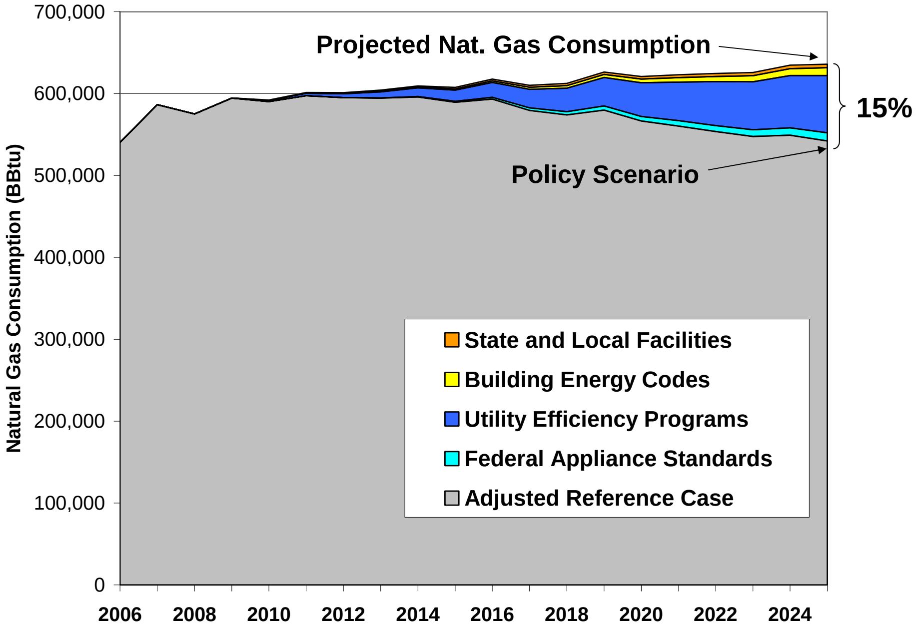


Figure 25. Share of Natural Gas Consumption Met by Energy Efficiency in Policy Scenario



Policy Investment and Program Costs

In this section, we report the estimated costs and benefits of the energy efficiency policy scenario to determine overall cost-effectiveness. There is no single way to determine whether energy efficiency is cost-effective, but rather there are multiple perspectives analysts take to determine cost-effectiveness of individual utility programs and portfolios of programs. Here, we examine the outlined energy efficiency policy scenario using two cost-effectiveness tests, the Total Resource Cost (TRC) test and the Participant Cost test (PCT).

The costs that are needed to run the efficiency policies and programs recommended for this policy scenario include the three following types: the customer investments in efficient technologies or measures; the program incentives paid to customers to cover the remaining technology/installation costs; and the administrative or marketing costs to run programs or administer policies. The technology investments might include any combination of incentives paid to customers or direct customer costs. See Table 17 for a breakdown of the total estimated costs in the policy scenario by benchmark year and Table 18 for a summary of costs by policy or program throughout the study time period (2009-2025).

Table 17. Annual Energy Efficiency Costs from Policy Analysis (Million 2006$)

	2010	2015	2020	2025
Customer/Private Investments	$ 310	$ 960	$ 1,210	$ 1,410
Incentives Paid to Customers	$ 140	$ 280	$ 330	$ 410
Admin/Marketing Costs	$ 35	$ 60	$ 75	$ 100
Total Costs	**$ 490**	**$ 1,300**	**$ 1,610**	**$ 1,920**

Note: These costs are undiscounted and shown in real 2006$

Table 18. Energy Efficiency Costs in Energy Efficiency Policy Scenario

Policies and Programs	Cumulative through 2025 (Millions 2006$)			Average Annual (Millions 2006$)		
	Customer/ Private Investments	Policy/ Program Incentives	Market-ing/ Admin. Costs	Customer / Private Invest-ments	Policy/ Program Incentives	Market-ing/ Admin. Costs
Appliance Efficiency Standards - Federal	$4,170	$0	$0	$250	$0	$0
Appliance Efficiency Standards - State	$1,560	$0	$3	$90	$0	$0
Building Energy Codes	$1,400	$0	$30	$90	$0	$2
Energy Efficiency Resource Standard (EERS)	$7,610	$4,210	$1,180	$450	$260	$60
Residential Programs	*$2,930*	*$2,900*	*$730*	*$170*	*$170*	*$40*
Commercial Programs	*$910*	*$910*	*$180*	*$50*	*$50*	*$10*
State Industrial Initiative	*$1,840*	*$0*	*$90*	*$110*	*$0*	*$5*
CHP policies and programs	*$1,920**	*$530*	*$8*	*$110*	*$30*	*$0*
Consumer Financial Incentives	$1,130	$570	$60	$70	$30	$3
State and Local Public Facilities	$440	$0	$40	$30	$0	$3
TOTAL	**$16,300**	**$4,900**	**$1,100**	**$960**	**$290**	**$70**

Note: All costs are undiscounted and shown in real, 2006$ and are rounded to the nearest tens. *CHP customer investments Include incremental customer fuel costs.

The section on macroeconomic impacts uses these cost assumptions to estimate impacts of the efficiency policies on the economy, including overall benefits to customers. Here, we report a net present value (NPV) analysis of costs and benefits to society (TRC) and to participants (PCT).

The results of the Participant Cost test (PCT), as shown in Table 19, indicate that the suite of energy efficiency policies shows a net benefit to participants over the study time period, with a benefit/cost ratio of 2.4. This test takes the perspective of a customer installing energy efficiency measure(s) in order to determine whether the participant benefits. The costs represent the costs to customers for purchasing or installing energy efficiency and the benefits are the savings on customers' electricity bills due to reduced consumption plus any incentives paid to customers. Readers should note, however, that although the study time period ends in 2025, participant energy savings from efficiency measures persist over the lifetime of each specific measure. Accounting for these additional savings beyond the study time period would yield a **benefit/cost ratio of 3.2**.

Table 19. Participant Cost Test for Energy Efficiency Policies (2008–2025)

By Policy/Program	NPV Costs	NPV Benefits	Net Benefit	B/C Ratio
Appliance Efficiency Standards - Federal	$ 2,320	$ 4,500	$ 2,170	1.9
Appliance Efficiency Standards - State	$ 950	$ 1,329	$ 380	1.4
Building Energy Codes	$ 750	$ 1,030	$ 280	1.4
Energy Efficiency Resource Standard (EERS)	$ 6,800	$ 19,150	$ 12,360	2.8
Residential Programs	*$ 3,320*	*$ 8,750*	*$ 5,430*	*2.6*
Commercial Programs	*$ 1,030*	*$ 6,210*	*$ 5,180*	*6.0*
*State Industrial initiative**	*$ 1,080*	*$ 2,860*	*$ 1,780*	*2.7*
*CHP Supporting Policies**	*$ 1,360*	*$ 1,330*	*$ (30)*	*1.0*
Consumer Financial Incentives	$ 1,010	$ 1,520	$ 510	1.5
State and Local Public Facilities	$ 280	$ 1,250	$ 970	4.5
Total	**$ 12,110**	**$ 28,780**	**$ 16,670**	**2.4**
By Sector	**NPV Costs**	**NPV Benefits**	**Net Benefit**	**B/C Ratio**
Residential	$ 6,590	$ 14,450	$ 7,860	2.2
Commercial	$ 3,510	$ 10,580	$ 7,070	3.0
Industry	$ 2,020	$ 3,750	$ 1,730	1.9
Total	**$ 12,110**	**$ 28,780**	**$ 16,670**	**2.4**

* These two policies are included in the costs and benefits of the EERS.

The Total Resource Cost (TRC) test, as shown in Table 20, evaluates the net benefits of the suite of *electricity* energy efficiency policies to the region as a whole. This test considers total costs, including investments in energy efficiency measures (whether incurred by customers or through incentives) and administrative or marketing costs. Benefits in the TRC test are the avoided costs of electricity, or the marginal generation costs that utilities avoid by reducing electricity consumption through efficiency, and were taken from the avoided energy resource costs developed by Synapse Energy Economics (see Appendix A). Because we only developed a set of electricity avoided costs to Pennsylvania, we evaluate here only costs and benefits related to electricity savings. The TRC test, which shows an overall benefit-to-cost ratio of 1.8, suggests a net positive benefit to Pennsylvania from implementation of these efficiency programs and policies. Accounting for benefits over the lifetime of the efficiency measures would yield a **benefit/cost ratio of 2.5**.

Table 20. Total Resource Cost (TRC) Test for Energy Efficiency Policies (2008–2025)

By Policy/Program	**NPV Costs**	**NPV Benefits**	**Net Benefit**	**B/C Ratio**
Appliance Efficiency Standards - Federal	$ 2,070	$ 3,240	$ 1,170	1.6
Appliance Efficiency Standards - State	$ 950	$ 970	$ 20	1.0
Building Energy Codes	$ 420	$ 490	*$ 70*	*1.2*
Energy Efficiency Resource Standard (EERS)	$ 5,670	$ 11,001	$ 5,329	1.9
Residential Programs	$ 2,710	$ 4,210	$ 1,490	1.6
Commercial Programs	$ 790	$ 3,990	$ 3,200	5.0
*State Industrial initiative**	$ 800	$ 1,870	$ 1,080	2.3
*CHP Supporting Policies**	*$ 1,370*	*$ 930*	*$ (440)*	*0.7*
Consumer Financial Incentives	$ 30	$ 80	$ 50	2.5
State and Local Public Facilities	$ 130	$ 810	$ 670	6.0
Total	**$ 9,280**	**$ 16,580**	**$ 7,310**	**1.8**
By Sector	**NPV Costs**	**NPV Benefits**	**Net Benefit**	**B/C Ratio**
Residential	$ 4,900	$ 6,985	$ 2,080	1.4
Commercial	$ 2,660	$ 6,890	$ 4,230	2.6
Industry	$ 1,710	$ 2,710	$ 1,000	1.6
Total	**$ 9,280**	**$ 16,580**	**$ 7,300**	**1.8**

*Note: These two policies are included in the costs and benefits of the EERS.

Pittsburgh and Philadelphia Policy Opportunities

The two major metropolitan regions in Pennsylvania, the areas including and surrounding Pittsburgh and Philadelphia, contribute significantly to Pennsylvania's overall economic growth and energy consumption. The Pittsburgh metro area has a population of about 2.4 million and about 1 million households, representing about 20% of the state. The Philadelphia region has a population of nearly 3.9 million and 1.5 million households, which represents about 30% of the state. Together, these two regions comprise 50% of the state's population and should be heavily targeted in efforts to increase energy efficiency in the Commonwealth. In this section we first provide background material on initiatives currently underway and then suggest some specific elements of the statewide policies and programs to expand efforts to target these two regions.

Pittsburgh

Currently, Pittsburgh has a variety of its own local initiatives and engages in local implementation of national and state initiatives aimed at reducing electricity demand and lowering greenhouse gas emissions. Drawing on municipal, community, and business action, the Pittsburgh Climate Action Plan has a goal of achieving a 20% reduction in greenhouse gases by 2023. The municipal measures in this plan aim to "lead by example," and include a requirement that all municipal buildings employ LEED building standards, mandatory energy audits of city-county buildings, and implementation of recommended retrofits, vending misers for vending machines in city-county buildings, LED exit signs in city-county buildings, and retrofitting mercury street lamps with more efficient models. As discussed in the state policy recommendations, making energy efficiency a priority in public buildings is an important way to lead by example while freeing up public dollars.

Suggested community actions include encouraging smart growth, adopting more stringent building energy codes than current 2006 IECC codes, encouraging better loan rates for energy-efficient retrofits and purchases of energy-efficient homes, and improving funding and efficiency of public transit. The Keystone Home Energy Loan Program offers low interest rate loans for efficiency retrofits in existing homes and the Federal Housing Administration's Energy-Efficient Mortgages program offers loans for new and existing homes. Through the Climate Action Plan, Pittsburgh proposes to make increased use of these programs.

Recommended business actions include promoting ENERGY STAR and LEED certified products, creating a “sustainable business” seal, and creating a green business award to encourage competition amongst businesses to increase efficiency. Through the Department of Environmental Protection, Pittsburgh offers an annual small business advantage grant in which participating businesses receive up to $7500 to perform EE improvements; under the condition that the businesses match all funds received 1:1. In 2007, 48 businesses received a total of $300,000 from this program and demand is continuing to rise at a rate that far exceeds available funds. Pittsburgh also encourages local implementation of several national and state efficiency programs, including Change a Light Day, Earth Hour, adoption of LED traffic lights, and installing efficient lighting fixtures in sports fields.[21]

Utility Low-Income Programs

Several local utility companies have adopted some successful efficiency programs as part of meeting the Pennsylvania low income utility requirement for large utility companies. These programs have proved to be great successes, with demand far outweighing available funding. Part of the reason for the success of these programs is the fact that many low income utility customers in Pittsburgh and Philadelphia live in multifamily buildings. Low income residents often present the greatest opportunity for efficiency savings in residential buildings because they tend to lack adequate insulation, efficient appliances, and other energy saving measures to a greater degree than do higher income residents. And by targeting multifamily buildings, programs are able to retrofit many apartments at once, resulting in significant efficiency gains.

Since 1988, Duquesne Light Co. has sponsored the Smart Comfort program for low-income customers as a part of it’s CAP program designed to help customers reduce their electricity demand, and in turn, their energy bills. Originally covering only customers with electric heat, the program has proved to be a success and has been to include all baseload electricity demand as well. The majority of participants live in large apartment buildings where retrofits have included changing light bulbs, removing water beds, replacing refrigerators and metering appliance use, among other measures. The cost of saved energy has averaged a scant $0.03 per kWh, making the program extremely cost effective. One of the primary reasons for the program’s success has been the creation of an energy manager to oversee the implementation of retrofits and educate program participants (Kukovich 2009). Other similar programs in the Pittsburgh area have been markedly less successful due to customers not receiving adequate education about the lifestyle changes necessary to help make retrofits successful methods of demand reduction.

Duquesne’s Smart Comfort Energy Audits are conducted through Conservation Consultants, Inc. (CCI), an energy efficiency consultancy firm based in Pittsburgh, which also conducts audits for customers of Dominion Peoples, Equitable, and Columbia Gas companies. CCI’s most common efficiency improvement recommendations include installing CFLs, ENERGY STAR certified appliances, and insulation. Audits are offered to low-income homes and multifamily buildings in certain neighborhoods in Pittsburgh.

In instances where electricity customers in multifamily buildings are not eligible for low-income assistance, programs are most successful when incentives are offered to building owners. For example, Affordable Comfort has aided the Pennsylvania Housing Finance Agency with a loan program called Preservation Thru Smart Rehab to encourage retrofits of apartment buildings. Preservation Thru Smart Rehab offers below market loans, shared savings financing, and leveraged certificates of deposit to property owners. Pilot projects have proved successful, but there have been several obstacles in the way of expansion. Attracting corporate investors has proved difficult, leading to a lack of available financing for interested building owners. Also, there is a need for more alternatives to mortgage-based financing for retrofit projects. Too often the property value is insufficient collateral for low income buildings, and building owners may have competing priorities for upgrades to their buildings. Frequently safety improvements take priority over energy efficiency retrofits. Going forward, the challenge will be to attract more corporate

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[21] http://www.city.pittsburgh.pa.us/district8/assets/08_pgh_climate_action_plan.pdf

investor interest in multifamily building energy conservation to allow more loans with lower interest rates.

Philadelphia

As a member of the Cities for Climate Protection run by ICLEI – Local Governments for Sustainability, the city of Philadelphia features a greenhouse gas initiative focusing on government leadership, public awareness, and a local action plan for increasing energy efficiency and reducing greenhouse gas emissions. As part of the GHG Initiative, Philadelphia is converting its traffic lights to efficient LED lights, and has currently converted 28,000 red lights, resulting in about 8,300 MWh savings. Community measures include the Sleep Is Good campaign that endorses adoption of sleep mode for computers, installation of energy-efficient vending machines, an ENERGY STAR program for public schools, weatherization of low-income homes, insulation upgrades and installation of faucet flow restrictors. initiative also encourages large scale government purchases of emerging energy-efficient technologies and increasing public awareness. Philadelphia also manages the Municipal Energy Office Energy Management Program, which encourages best practices in procurement, construction and facility management.

Additionally, Philadelphia boasts a Local Action Plan outlining a number of proposals for energy savings and efficiency. Recommended for immediate action are: requiring the purchase of ENERGY STAR qualified products for all US EPA listed product categories, and NEMA premium electric motors for all bid solicitations and RFPs for both public works and SSE (Service Supply and Equipment) contracts issued by the procurement department; requiring LEED certification for General, Aviation, and Water Fund new construction and major renovation projects over 10,000 square feet of gross floor area; reducing energy use for General Fund utility accounts by five percent from 2006 levels by 2010; adopting codes and development strategies for "transit-oriented development" and "green building"; and reducing vehicle fuel consumption. Additional proposals include: increasing assistance for weatherization programs; promoting combined heat and power systems at city complexes; and promoting implementation of demand side management programs by local utilities.[22]

The City of Philadelphia's draft Sustainability plan from January 2009 contains a series of goals for the city for 2009-2015 aimed at reducing energy consumption, environmental footprint, and vulnerability to rising energy prices, as well as increasing sustainability. The plan proposes to reduce city government energy consumption by 30% by 2015, citywide building energy consumption by 10%, and retrofit 15% of housing stock (100,000 projects) with insulation, air sealing, cool roofs, and smart meters. All told, the plan proposes to save nearly 15 million MMBtu, while producing almost 3 million MWh through renewable energy. In addition to energy efficiency and conservation, the plan calls for purchasing/generating 20% of electricity from renewable energy sources and reducing greenhouse gas emissions by 20%. A public release of Philadelphia's energy plan is expected in April 2009 (Robinson 2009).

Policy Recommendations for Philadelphia and Pittsburgh Metro Regions

The statewide policy recommendations discussed in the previous section can have a significant impact on the Philadelphia and Pittsburgh metro areas. As regions that comprise about 50% of the state in terms of population and energy consumption, they represent important regions to target as part of overall statewide efforts in order to reach statewide goals. For example, the policies to advance energy efficiency standards at both the federal and state levels will result in significant energy savings for the metro regions. There are specific actions, however, which municipalities in these regions should pursue.

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[22] http://www.phila.gov/green/LocalAction/pdf/PhiladelphiaClimateChangeLocalActionPlan2007.pdf

Building Energy Codes and Enforcement

Although building energy codes are set at the state level, municipalities have the option to set more stringent targets to go beyond code and also must implement the training necessary for officials to enforce state level codes. Training for code officials, design professionals, and building contractors is crucial to ensure high quality inspections and code compliance. When Pennsylvania updated its residential building energy code in 2004, most municipalities opted to take the responsibility of enforcement, though prior to this relatively few municipalities were equipped to perform this task (Turns 2008). We estimate that stringent building energy codes consistent with those recommended for statewide code, coupled with strong municipal enforcement resources, have the potential to save 1,100 BBtu of natural gas in both Philadelphia and Pittsburgh metropolitan regions.

Consumer Financial Initiatives

Local implementation of consumer financial initiatives plays a fundamental role in fuel oil energy savings. Since residents who heat with fuel oil usually purchase oil locally, municipalities should take a proactive role in targeting this important potential for increased efficiency. We estimate that by 2025 Pittsburgh and Philadelphia can realize savings of approximately 20 million gallons and 40 million gallons of fuel oil respectively, or 10% of consumption.

State and Local Facilities

Through Pennsylvania’s existing energy savings performance contract (ESPC) model for energy retrofits in public facilities, the Pittsburgh and Philadelphia metro regions have significant potential to increase energy efficiency of government buildings. The City of Philadelphia’s draft energy plan sets a goal of reducing lower city government energy consumption by 30% by 2015. Likewise, the Pittsburgh Climate Action Plan lays out a series of measure aimed at reducing energy consumption in municipal buildings. Our analysis shows a potential to reduce state and local facility electricity consumption by about 500 GWh in Pittsburgh and 700 GWh in Philadelphia.

Low-Income Energy Efficiency Programs

The Pennsylvania low-income utility program requirement presents one of the best opportunities for local implementation of low-income programs. These programs have been very popular and successful so far, with demand greatly exceeding funding supply to date. Due to the large number of low-income residents living in Philadelphia and Pittsburgh, especially in multifamily buildings, additional funding for local programs can lead to significant energy savings while assisting those with the greatest financial need.

Saving energy is more difficult in multifamily housing due primarily to two complications: 1) these housing units represent a disproportionately large number of low-income residents and residents living below the poverty line; and 2) the split incentive problem—that is, the party who owns the property and is responsible for capitol investments and upkeep (landlord) typically is not the same party who is responsible for paying energy costs (tenant). However, because multifamily buildings represent over a quarter of the housing units in the U.S. and comprise 20% of energy consumed by all housing units, it is essential to target energy efficiency policies at this important sector.

Onsite PV

Meeting the Alternative Energy Portfolio Standard will require local implementation of statewide goals. Installations are often performed by local companies, and rooftop installations provide a readily available outlet for local production of solar energy. Our analysis of local onsite PV production shows a technical potential of about 700 GWh for Pittsburgh and 1,000 GWh for Philadelphia by 2025, or about 2% or electricity demand.

Pittsburgh Policy Analysis Results

Policies and Programs	**Electricity**		**Peak Demand**		**Natural Gas**		**Fuel Oil**	
	GWh	%*	MW	**%***	BBtu	%*	MilGal	%*
Federal Appliance Standards	1,500	4%	400	5%	1,200	3%	0.1	<0.1%
State Appliance Standards	400	1%	80	1%	NA	NA	NA	NA
Building Energy Codes	300	1%	70	1%	1,100	3%	NA	NA
Energy Efficiency Resource Standard (EERS)								
Res. Buildings Programs	2,400	6%	460	6%	3,200	8%	NA	NA
Comm. Bldgs Programs	3,000	8%	540	7%	1,200	3%	NA	NA
Industrial Initiative	900	2%	160	1%	1,600	4%	NA	NA
CHP Policies and Incentives	600	2%	40	1%	NA	NA	NA	NA
EERS - Subtotal	6,900	18%	1,200	15%	6,600	15%	NA	NA
Consumer Financial Initiatives	7	<0.1%	1	<0.1%	150	0.4%	20	10%
State and Local Facilities	500	1%	80	1%	300	1%	2	1%
Onsite PV	700	2%	NA	NA	NA	NA	NA	NA
Total	**10,300**	**27%**	**1,800**	**23%**	**9,400**	**22%**	**22**	**11%**

*Note: Percent (%) reductions are presented as a fraction of projected energy use in the reference case.

Philadelphia Policy Analysis Results

Policies and Programs	**Electricity**		**Peak Demand**		**Natural Gas**		**Fuel Oil**	
	GWh	%*	MW	**%***	BBtu	%*	MilGal	%*
Federal Appliance Standards	2,000	3%	500	5%	900	2%	0.1	<0.1%
State Appliance Standards	600	1%	100	1%	NA	NA	NA	NA
Building Energy Codes	400	1%	80	1%	1,100	2%	NA	NA
Energy Efficiency Resource Standard (EERS)								
Residential Buildings Programs	3,200	6%	700	6%	2,600	5%	NA	NA
Commercial Buildings and Industrial Programs	5,000	9%	1,000	10%	3,400	6%	NA	NA
EERS - Subtotal	8,200	16%	1,700	16%	6,000	11%	NA	NA
Consumer Financial Initiatives	9	<0.1%	2	<0.1%	120	0.2%	40	10%
State and Local Facilities	500	1%	100	1%	400	1%	3	1%
Onsite PV	1,000	2%	NA	NA	NA	NA	NA	NA
Total	**12,700**	**24%**	**2,500**	**24%**	**8,500**	**16%**	**43**	**11%**

*Note: Percent (%) reductions are presented as a fraction of projected energy use in the reference case.

Pittsburgh and Philadelphia Job Allocation and Wages Analysis

Pittsburgh and Philadelphia metropolitan regions comprise about 50% of the jobs and wages created by implantation of energy efficiency policies in Pennsylvania. Of the more than 27,000 jobs that we estimate will be created by energy efficiency programs, over 14,000 are expected in Pittsburgh and Philadelphia alone. This significant percentage underscores the importance of local policy implementation for these key metropolitan regions. Our analysis shows a net increase of about 5,500 jobs for the Pittsburgh metropolitan area and around 9,000 in Philadelphia by the year 2025. These jobs will provide approximately $223 million in wages for Pittsburgh and $364 million for Philadelphia. The drop in wages by 2015 reflects the fact that the Pennsylvania economy is heavily involved with coal mining and other fossil fuel resources. It takes several years for the state's economy to adjust to the new job opportunities. However, our method of allocating job and wage gains to Pennsylvania's metro areas is based on demographic information, such as total number of households, and does not reflect the unique mix of jobs found in Pittsburgh and Philadelphia. Particularly of note, the distribution of jobs in mining and other fossil fuel resources is not concentrated in the Pittsburgh and Philadelphia metro regions. Jobs associated with fossil fuel resources are located primarily in Pennsylvania's rural and suburban areas. Therefore, net wage and job loss in 2015 is overestimated in metro areas.

Pittsburgh and Philadelphia Job Allocation and Wages Analysis Results

	2010	2015	2020	2025	%of State
Pittsburgh					
Jobs	350	400	3,000	5,500	20%
Wages (Million 2006 $)	$7	($7)	$90	$223	
Philadelphia					
Jobs	550	600	4,800	9,000	33%
Wages (Million 2006 $)	$12	($11)	$146	$364	

PENNSYLVANIA SOLAR ASSESSMENT

Sunshine is an abundant resource that is increasingly being used throughout the world to produce electricity, heat water, and provide space heating for buildings. Although historically Pennsylvania's energy economy has been associated with non-renewable resources, including early development of the oil industry, coal mining, and the nuclear industry, the potential for capturing renewable energy, including large scale wind and solar is starting to be recognized.

The amount of solar radiation in Pennsylvania is significant and is greater, for example, than Germany's which has the largest amount of installed solar energy capacity of any nation in the world. This study indicates that solar energy can be utilized as a major source of energy in Pennsylvania in the future, helping to diversify the current portfolio of coal, oil, natural gas, nuclear, and (more recently) wind power. The increased use of solar electricity and heating could provide numerous benefits to ratepayers and consumers, including:

- Decreased reliance on fossil fuels imported from other countries (some of whom are politically unstable);
- Reduction in greenhouse gas emissions that contribute to climate change;
- Stabilized and predictable energy costs for consumers (since solar equipment and installation costs are well understood and are not subject to fuel price escalation);
- Development of new jobs and increased employment through expansion of the renewable energy sales, installation, and service infrastructure;
- Creation of new manufacturing and distribution jobs (as solar manufacturers invest in new plants located closer to major markets); and
- Decreased flow of energy expenditures outside of the state, as more energy is produced using indigenous, renewable resources.

This section of the report assesses the technical and market potential for increased solar energy use for electricity, hot water, and air heating in Pennsylvania. The focus is on the use of building roof tops for solar electric and hot water systems and the use of building facades for solar hot air heating. These estimates therefore only capture a portion of the total solar resource potential, which can include the use of spaces such as parking lots, highway exclusion zones, and ground mounted systems. Major findings are summarized below and discussed in more detail in Appendix F.

Public Policy Support for Increased Solar Energy Use

As shown in Table 21, the Governor, the Legislature, and state regulatory bodies in Pennsylvania have demonstrated leadership by establishing several public policies and program initiatives that support expansion of solar energy use in the state.

Table 21. Solar Energy Policy and Program Initiatives in Pennsylvania

Alternative Energy Portfolio Standard	Passed in 2004	Sets goal of 860 MW PV by 2021. Specifies solar water heating a potential efficiency option for offsetting electric water heating.
Alternative Energy Investment Fund	Enacted July 2008	Sets aside $100 Million for a solar incentive program. Establishes $80 Million for economic development for solar manufacturers and large scale projects.
Net Metering	Enacted 2004 Updated 2008	For residential solar up to 50 kW. For nonresidential solar up to 3 MW. For nonresidential solar > 3 MW and < 5 MW, if available to the grid for emergencies.
Standardized Interconnection Rules (SIR)	Enacted 2008	Establishes standardized fees and streamlined application process for customer-sited distributed generation.

A cornerstone of the state's energy policy is the Alternative Energy Portfolio Standard (AEPS) enacted in 2004.[23] The AEPS requires Pennsylvania's electric utilities to acquire a minimum of 18% of their electricity from alternative energy sources by 2021 (8% from Tier I resources and 10% from Tier II). In the AEPS, photovoltaics are part of a broader grouping of clean energy resources bundled into Tier I, with the requirement that 0.5% of total electricity sales be achieved from that tier by 2021. To achieve this goal, it is estimated Pennsylvania will need to install 860 MW of new solar generation in the next 12 years. In addition, the AEPS specifies solar water heating as an option in Tier II (which also addresses energy efficiency). As such, increased attention to solar water heating opportunities is expected in the state by public policymakers, utility regulators, and the energy industry during the coming years.

Other important components of Pennsylvania's energy policy framework include the: Alternative Energy Investment Fund (AEIF) which sets aside $100 M to cover up to 35% of the installed cost of solar technologies for residential customers and small businesses; the $80 million economic development fund created as part of the AEIF; net metering regulations that enable owners of customer-sited distributed generation (such as PV) to obtain retail credit from utilities for power produced on site; and Standardized Interconnection Rules that simplify and streamline interconnection for grid-connected distributed generation. [24]

Current Status of the Solar Industry

Overall, solar energy technologies are technically proven, available off-the-shelf, manufactured either in the U.S. or imported from other countries, and distributed on a widespread basis throughout Pennsylvania (and most other states) by reputable national and regional companies. There is a solar installation infrastructure already in place in Pennsylvania, although it is small compared to other energy sectors. A potential customer in Pennsylvania interested in buying solar electric, water heating, and/or space heating equipment today can pick up the telephone,

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[23] http://www.puc.state.pa.us/electric/pdf/AEPS/AEPS_Ann_Rpt_2007.pdf

[24] http://www.depweb.state.pa.us/energindependent/lib/energindependent/documents/factsheets/alternative energyinvestmentfund.pdf

place an order, receive a firm price, and confirm a delivery and installation date for their solar energy system. Typically, the installation will be done by a local installer (many of whom are relatively small “Mom and Pop” businesses). Although currently most, if not all, of the components used in the solar system will not be manufactured in Pennsylvania, this is expected to change as several start-up solar manufacturers begin and/or expand their operations in Pennsylvania.

Pennsylvania Poised for Growth in Solar Energy Use

Although currently less than 1% of all energy used by Pennsylvania homes, businesses, and industries is obtained from solar energy, this could increase significantly in the future. Key public policies are in place that support increased solar energy use, a regulatory framework that is favorable for renewable energy generation is taking shape, the beginnings of an installation infrastructure are in place, the solar manufacturing industry is starting to develop, and consumer interest in “going green” is growing. The rate at which solar technologies will be deployed and used over the next 5, 10, and 15 years — and the extent to which they end up meeting state goals — will depend in part on a variety of factors, discussed below.

Technical Potential for Solar Energy Use

A starting point for assessing the potential for future solar energy use in any state is to estimate the overall technical potential for solar electricity using photovoltaics (PV), solar water heating (SWH), and solar air heating (SAH). In this document, technical potential is defined as the upper limit for future solar energy use based on the building stock, roof area, and other key characteristics of Pennsylvania. The methodology for assessing technical potential is based on an approach developed by the National Renewable Energy Laboratory (NREL) that assesses the number of rooftops available and other key building stock and population data. The methodology is discussed in more detail below.

Results of the technical potential analysis are presented in Table 22. As shown in the table, the technical potential exists in Pennsylvania for solar resources to offset a total of 28,894 GWh and 66.4 TBtu of conventional electric generation and fossil fuels statewide. Achieving the technical potential would result in offsetting 20% of all residential energy use and 39% of all commercial energy use with solar.

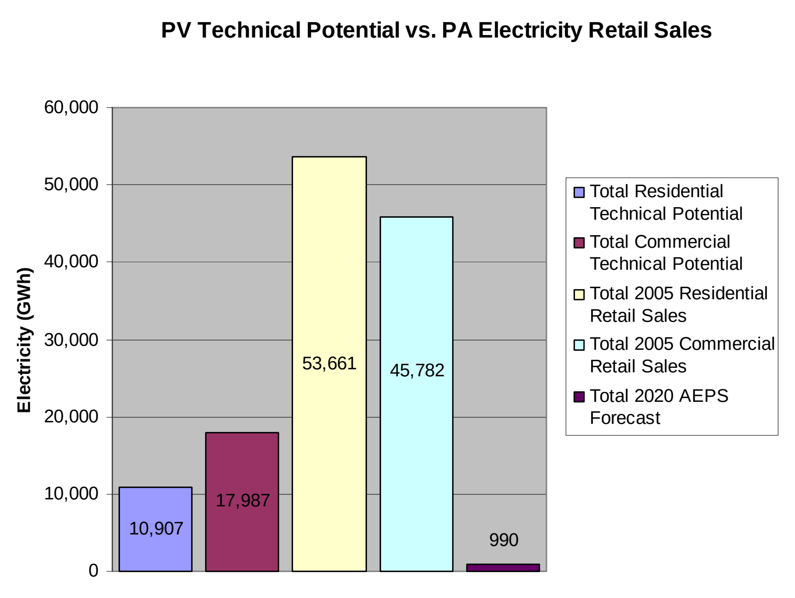
Table 22. Technical Potential for Solar Energy Use in Pennsylvania

	Photovoltaics (MW dc)	**Photovoltaics** (GWh)	**Solar Hot Water** (TBtu)	**Solar Air Heating** (TBtu)
Statewide:				
Residential	10,388	10,907	9.1	N/A
Commercial	17,131	17,987	21.3	36.0
Total	**27,519**	**28,894**	**30.4**	**36.0**
Philadelphia Metro Area:				
Residential	3,070	3,428	2.7	N/A
Commercial	5,641	6,298	7.0	11.7
Total	**8,711**	**9,726**	**9.7**	**11.7**
Pittsburgh Metro Area:				
Residential	2,097	2,132	1.8	N/A
Commercial	3,375	3,431	4.2	7.1
Total	**5,472**	**5,563**	**6.0**	**7.1**

In addition, large metropolitan areas provide unique opportunities for implementing solar energy initiatives, and sometimes have specific transmission grid and peak load issues that benefit from geographically targeted implementation strategies. With this in mind, the technical potential for solar electricity was also assessed for the two largest metropolitan areas in Pennsylvania. As shown in Table 2, the technical potential exists in the Philadelphia metropolitan area for offsetting 9,726 GWh and 21.4 TBtu (or 34% of the statewide total) with residential and commercial solar technologies. In the Pittsburgh metropolitan area, the technical potential exists for offsetting 5,563 GWh and 13.1 TBtu (or 19% of the statewide total) with residential and commercial solar technologies.

Presented in Figure 26 is a comparison of total energy consumption sales and PV generation. As shown in the figure, the technical potential exists for solar energy to provide significant in-state energy resources for Pennsylvania and to far exceed the AEPS solar goal.

Figure 26. PV Technical Potential Compared to Annual Electric Requirements and AEPS Targets



Market Potential for Rooftop Photovoltaics in Pennsylvania

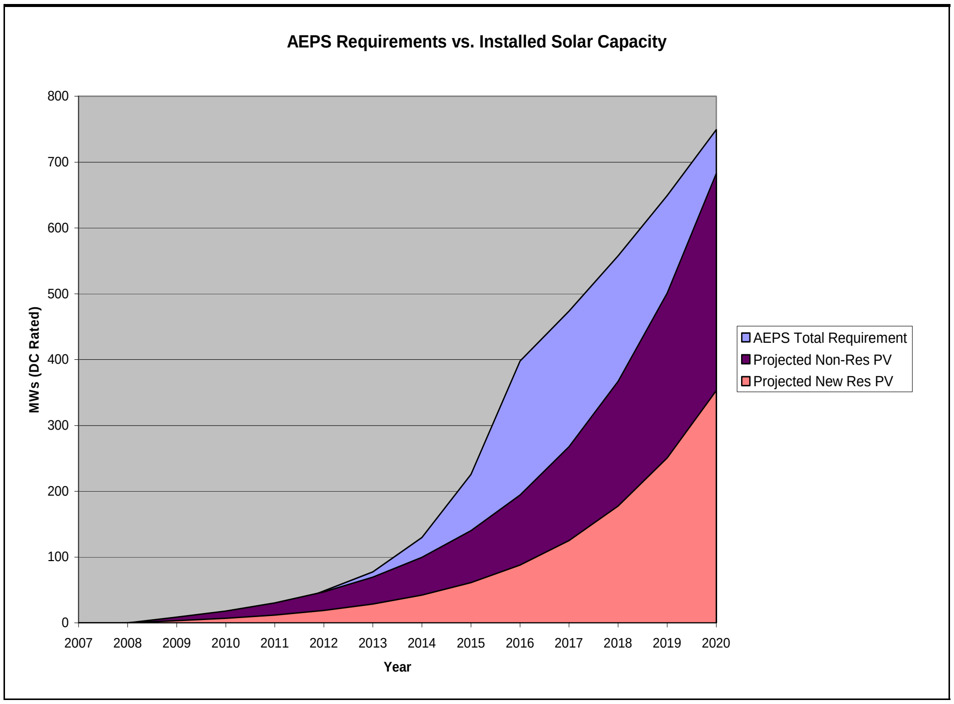
In addition to assessing technical potential, a high level analysis of customer-sited rooftop PV market potential was conducted for this study. Results of the scenario provide indicators of expected market growth, based on current initiatives and market support strategies. The scenario analysis is general in nature and provides a broad overview of market development potential. Looking forward, this work could be supplemented in the future by more detailed analyses of specific policies, program designs, and business development plans.

Table 23 presents a high level scenario involving the known elements of Pennsylvania's PV interconnection and net metering policies, set-aside goals mandated by the AEPS, and the forthcoming AEIF incentive program for 2009. The residential market potential is supported through the $100M AEIF funding and assumes an 8-year market transition through a year over year reduction in incentives, averaging at 35% of the 2009 installed system cost. With a 40% estimated growth rate, the 5-year AEIF program results in 30 MW of installed residential PV capacity and 40 MW of large-scale (75 kW DC) commercial roof top systems. Longer term, the program initiates growth that could contribute an estimated 680 MW by 2020 or approximately 80% of the AEPS goal of 860 MW of equivalent solar capacity (see Figure 27).

Table 23. Market Potential for Solar Energy Use in Pennsylvania

	Projected Market Potential	
Market Segment	**2009-2013**	**2020**
Residential Photovoltaic:		
Installed Capacity	**~30 MW**	**~350 MW**
Program Support	**~$60 million**	**~$110 million**
Number of Systems	**~7,000**	**~90,000**
Commercial Roof Top PV:		
Installed Capacity	**~40 MW**	**~330 MW**
Program Support	**~$40 million**	**-**
Number of Systems	**~550**	**~4,400**

Figure 27. AEPS Requirements vs. Installed Solar Capacity



These results suggest that a significant share of the resources needed to meet photovoltaic goals in the AEPS can be obtained from residential and commercial rooftop systems. As noted in the remainder of this report, however, obtaining these levels of market growth will require sustained public and private investments, as well as sustained policy support and the implementation of strategies to help reduce remaining market barriers and enable the rapid growth rates associated with this scenario. The program investments associated with the market potential scenario are consistent with anticipated investments of the Pennsylvania Alternative Energy Investment Fund.

When comparing the market potential to the AEPS goals, the results suggest that for the next few years as the utility specific requirements for PV ramp up, program assisted market development should keep pace, or perhaps exceed, the AEPS targets. This is particularly true if additional utility scale projects are developed. As the requirement percentages accelerate, particularly through 2016, a growing need for resources beyond projected market growth in the rooftop market is apparent.

The market potential results also indicate that within five years, upwards of 7,000 new residential and 550 new commercial rooftop PV systems could be installed statewide. These accomplishments, and the market development required, represent only a fraction of the goals that have been set for 2020, and an even smaller fraction of the overall potential. They will require concentrated effort, multi-year investment, and new delivery capacity to enable the sustained orderly growth of the solar industry.

Pathways for Achieving Market Potential

The existing Alternative Energy Portfolio Standard, Alternative Energy Investment Fund, net metering regulations, and Standardized Interconnection Rules in Pennsylvania are extremely important and serve as early catalysts for enabling the state to capture the benefits of increased solar energy use. However, continued thought, care, and action will be needed to ensure the state meets existing (or anticipated) solar targets rapidly and cost-effectively. Looking forward, programs, policies, and investments in Pennsylvania will need to be tailored to reduce and remove the market barriers to greater solar market development. The strategies likely to be most useful are shown in Table 24.

At present, Pennsylvania is pursuing additional policies to address these and other challenges. Legislation has been introduced to set a firm price and schedule for the solar alternative compliance payment (SACP) levels to align with those set in neighboring states. This would set a cap and could provide greater certainty of the value of solar renewable energy credits to the market and help to obtain financing. Currently, the SACP level in Pennsylvania is established at 200 percent of the regional average market price without a cap. While the 200 percent factor provides a strong signal to the obligated entities to be active in the market rather than pay the penalty associated with the SACP, establishing a forward long-term schedule for the SACP cap would make Pennsylvania's market structure more consistent with other states in the region. This consistency, in turn, could make project financing easier.

Additional policies Pennsylvania could consider include the following:

- Expand upon the number of applications of the virtual net metering model, which limits projects to within a 2-mile radius.
- Continue to monitor the AEPS targets and achievements for solar, and extend and/or increase the goals as appropriate as is currently proposed in H.B. 80. Increasing goals in the out years will better position Pennsylvania to take advantage of solar as a climate change mitigation option.
- Provide model permitting ordinances for local municipalities to keep the process simple without undue obstacles for siting and permitting solar.

Table 24. The Challenges Ahead and Strategies

Challenges	Possible Strategies
Addressing High "First Time" Costs	Provide incentives to reduce initial system cost. Offer financing to "cash flow" upfront costs thru monthly payments and explore the alternative models for solar deployment such as solar leasing models. Incentivize the integration of solar equipment in new buildings. Some "Tier III" support and incentive program examples are currently being developed in the Northeast, and will typically offer advanced technical assistance, modeling and plan review, and substantial new construction incentives. Waive state sales tax for solar PV and thermal equipment. Limit or waive potential property tax increases based on solar installations.
Developing the Installation Infrastructure	Support installation infrastructure, including installers and code officials, through workforce development and installer and inspector job training Solar installer training and certification using nationally recognized certification training centers and protocols. Use stimulus funding to support workforce development beyond the approaches available through Labor & Industry.
Ensuring Equipment Availability	Active recruitment and incentives to attract manufacturers of solar panels and system components throughout PA; support expanded distribution networks.
Assuring Quality and Performance	Develop quality assurance and inspections programs that maximize system performance thru proper design, siting, and installation. Inspect enough systems, particularly in the early years of the program to ensure a high level of professional installations.
Timely Process of Applications	Design program capacity to keep up with application flow and inspections.
Stimulating Consumer Demand	Utilize education and outreach programs to stimulate consumer demand and provide consumer protection information, e.g., providing consumer-friendly information on state agency websites and managing an up-to-date certified installer list.

DEMAND RESPONSE

This section defines Demand Response (DR), assesses current DR activities in Pennsylvania, uses benchmark information to assess DR potential in Pennsylvania, and concludes with policy recommendations that could foster DR contributing appropriately to the resource mix in Pennsylvania that can be used to meet electricity needs. Potential load reductions from DR are estimated for a set of DR programs that represent the technologies and customer types that span a range of DR efforts.

Defining Demand Response

DR focuses on shifting energy from peak periods to off-peak periods and clipping peak demands on days with the highest demands. Within the set of demand-side options, DR focuses on clipping peak demands that may allow for the deferral of new capacity additions and enhance operating reserves to mitigate system emergencies. Energy efficiency focuses on reducing overall energy consumption with attendant permanent reductions in peak demand growth. Taken together, these two demand-side options can provide opportunities to more efficiently manage growth, provide customers with increased options to manage energy costs and develop least cost resource plans.

DR resources are usually grouped into two types: 1) load-curtailment activities where utilities can "call" for load reductions; and 2) price-based incentives which use time-differentiated and/or dispatchable rates to shift load away from peak demand periods and reduce overall peak-period consumption. Interest in both types of DR activities has increased across the country as fuel input prices have increased, environmental compliance costs have become more uncertain, and the substantial investment in overall electric infrastructure needed to support new generation resources.

The summary of DR potential presented in Table 25 focuses on load-curtailment and backup generation and does not include savings resulting from price-based incentives. Residential load-curtailment typically involves direct load control (DLC) of air conditioners—although this can also cover appliances—as well as temperature offsets, which increase thermostat settings for a certain period of time. Commercial and industrial applications of DR focus on load control of space conditioning equipment, however this depends on customer size: self-activated load reductions are usually more prudent for larger customers. Backup generation for commercial and industrial applications involves generators with start-up equipment that allows them to come online with short notice from utilities, relieving the additional demand on the system during peak hours.

Rationale for Investigating Demand Response

DR alternatives can be implemented to help ensure that a utility continues to provide reliable electric service at the least cost to its customers. Specific drivers often cited for DR include the following:

- **Ensure reliability—**DR provides load reductions on the customer side of the meter that can help alleviate system emergencies and help create a robust resource portfolio of both demand-side and supply-side resources that meet reliability objectives.
- **Reduce supply costs—**DR may be less expensive per megawatt than other resource alternatives.
- **Manage operational and economic risk through portfolio diversification—**DR capability is a resource that can diversify peaking capabilities. This creates an alternative means of meeting peak demand and reduces the risk that utilities will suffer financially due to transmission constraints, fuel supply disruptions, or increases in fuel costs.
- **Provide customers with greater control over electric bills –**DR programs would allow customers to save on their electric bills by shifting their consumption away from higher cost hours and/or responding to DR events.
- **Address legislative/regulatory interest in DR –** Recent legislation, Pennsylvania Act 129, calls for peak load reduction, smart meter deployment, and the availability of time-based rates for all customers.

Demand Response in Pennsylvania—Background

A sound strategy for development of DR resources requires an understanding of Pennsylvania's demand and resource supply situation, including projected system demand, peak-day load shapes, and existing and planned generation resources and costs.

Pennsylvania utilities serve 5.2 million residential facilities and almost 700,000 non-residential facilities (EIA 2007b), providing power that is expected to have a system peak load of almost 34,000 MW in 2008 (ACEEE base case for Pennsylvania).

Electricity demand in Pennsylvania has grown at a rate of 1.8 percent annually in the past 15 years (PUC 2008b). This is an aggregate figure for all sectors, including industrial, commercial and residential. Average total sales growth from 2002 to 2007 was also 1.8 percent. Aggregate sales in 2007 totaled approximately 149 billion kWh, and are projected to grow at 1.4 percent annually to 2012. This includes a residential growth rate of 1.5 percent, a commercial growth rate of 1.6 percent and an industrial growth rate of 1.1 percent.

The Electric Power Outlook for Pennsylvania 2007-2012 concludes that there is sufficient generation, transmission and distribution capacity to reasonably meet the needs of Pennsylvania consumers for the near future, with generation adequacy concerns beginning in 2013 (PUC 2008b). By 2013, additional capacity resources of 1,500 MW will likely be needed to maintain a 15% reserve margin (PUC 2008b).[25] Therefore, new capacity and infrastructure investments are needed. Increasing fuel and electricity costs, the potential for additional environmental restrictions, and the elimination of price caps will increase the importance in assessing future resources and DR potential.

Role of Demand Response in Pennsylvania's Resource Portfolio

The DR capabilities deployed by Pennsylvania utilities can become part of a long-term resource strategy that also includes resources such as traditional generation resources, power purchase agreements, options for fuel and capacity, and energy efficiency and load management programs. Objectives include meeting future loads at lower cost, diversifying the portfolio to reduce operational and regulatory risk, and allow Pennsylvania customers to better manage their electricity costs.

The 2005 Energy Policy Act provisions for Demand Response and Smart Metering has lead to a number of states and utilities piloting and implementing a Smart Grid, or sometimes referred to as Advanced Metering Infrastructure (AMI). Smart Grid is a transformed electricity transmission and distribution network or "grid" that uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability and safety of power delivery and use. For energy delivery, the Smart Grid has the ability to sense when a part of its system is overloaded and reroute power to reduce that overload and prevent a potential outage situation. Principal benefits of Smart Grid technologies for DR include increased participation rates and lower costs.

The growth of renewable energy supply (and plans for increased growth) can also increase the importance of DR in the portfolio mix. For example, sudden renewable energy supply reductions (e.g., from an abrupt loss in wind) may be mitigated quickly with DR.

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[25] This forecast does not include thousands of megawatts of "possible capacity additions" identified by the PJM and Midwest ISO generation interconnection queues as projects in service after 2012. These projects are not counted toward meeting reserve requirements as this capacity is not committed to serve regional load

Assessment of Demand Response Potential in Pennsylvania

Table 25 shows the resulting load shed reductions possible for Pennsylvania, by sector, for years 2015, 2020, and 2025. Load impacts grow rapidly through 2018 as program implementation takes hold. After 2018, the program impacts increase at the same rate as the forecasted growth in peak demand.

The high scenario DR load potential reduction is within a range of reasonable outcomes in that it has an eleven year rollout period (beginning of 2010 through the end of 2020), providing a relatively long period of time to ramp up and integrate new technologies that support DR. A value nearer to the high scenario than the medium scenario would make a good MW target for a set of DR activities.

The high scenario results show a reduction in peak demand of 2,313 MW is possible by 2015 (6.3% of peak demand); 4,860 MW is possible by 2020 (13.2% of peak demand); and 5,077 MW is possible by 2025 (13.8% of peak demand).

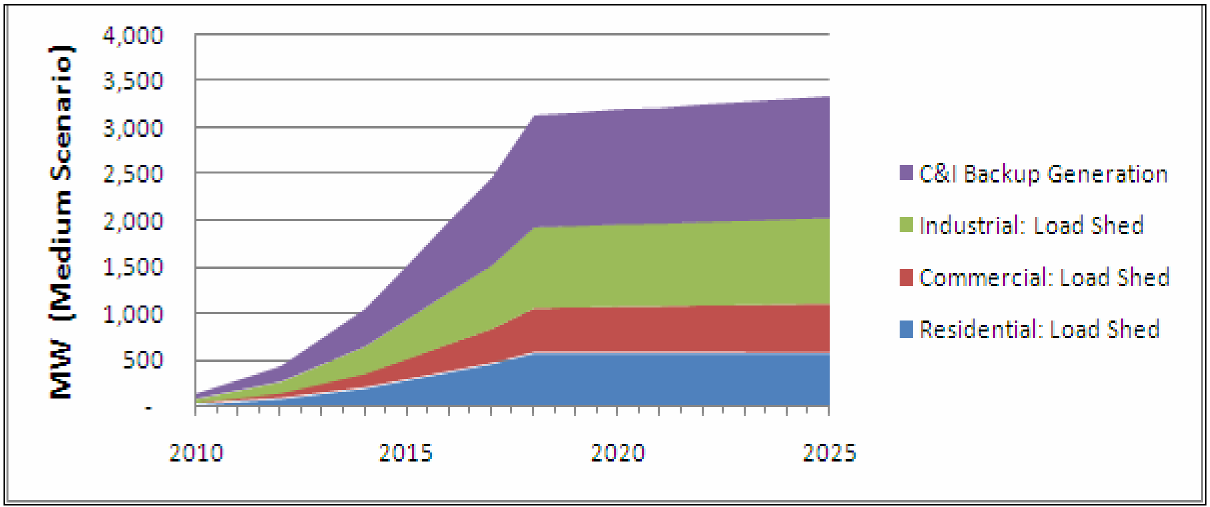
The more conservative medium scenario results show a reduction in peak demand of 1,523 MW is possible by 2015 (4.1% of peak demand); 3,199 MW is possible by 2020 (8.7% of peak demand); and 3,339 MW is possible by 2025 (9.1% of peak demand).

Table 25. Summary of Potential DR in Pennsylvania, By Sector, for Years 2015, 2020, and 2025[a]

	Low Scenario			Medium Scenario			High Scenario		
	2015	2020	2025	2015	2020	2025	2015	2020	2025
Load Sheds (MW):									
Residential	174	350	347	290	583	578	406	816	809
Commercial	85	184	198	226	491	529	425	920	992
Industrial	189	394	409	425	887	921	755	1,576	1,637
C&I Backup Generation (MW)	436	928	983	582	1,238	1,311	727	1,547	1,639
Total DR Potential (MW)	884	1,856	1,938	1,523	3,199	3,339	2,313	4,860	5,077
DR Potential as % of Total Peak Demand	2.4%	5.1%	5.3%	4.1%	8.7%	9.1%	6.3%	13.2%	13.8%
a. See Section 3 for underlying data and assumptions.									

Figure 28 shows the resulting load shed reductions possible for Pennsylvania in the medium scenario, by sector, from year 2010, when load reductions are expected to begin, through year 2025.

Figure 28. Potential DR Load Reductions in Pennsylvania by Sector (Medium Scenario)



These estimates reflect the level of effort put forth and utilities are recommended to set targets for the high scenarios. These estimates are based on assumptions regarding growth rates, participation rates, and program design. These factors are discussed in Chapter 3. In developing these DR potential estimates, the integration of DR with select energy efficiency activities was considered to help ensure that load impacts were not double counted. The estimated load reduction per program participant is conservatively estimated to account for increased energy efficiency in the future.

Recommendations

Pennsylvania Act 129 requires electric distribution companies to reduce peak demand by 4.5% by May 31, 2013. This analysis estimates that 3.1% reductions in peak demand are possible by 2013 through DR policies alone. This result is applicable for between 80 and 100 hours of peak demand. Energy efficiency reductions will provide further reductions, with opportunities to exceed the Act 129 goal.

Key recommendations include:

- It is important that the DR programs be integrated with the delivery of EE programs. Many gains in delivery efficiency are possible by combining and cross-marketing EE and DR programs. These can include new building codes and standards that include not only energy efficiency construction and equipment, but also the installation of addressable and dispatchable equipment. This can include addressable thermostats in new residences and the installation of addressable energy management systems in commercial and industrial buildings that can reduce loads in select end-uses across the building/facility. In addition, energy audits of residential or commercial facilities can also include an assessment of whether that facility is a good candidate for participation in a DR program through the identification of dispatchable loads. Furthermore, building commissioning and retro-commissioning EE programs that are becoming popular in many commercial and industrial sector programs have the energy management system as a core component of program delivery. At this time, the application of auto-DR can be assessed and marketed to the customer along with the EE savings from these site-commissioning programs.

- Additional programs that be considered for roll-out and can be designed within a 12-month period include:

  - Residential and small business AC direct load control using switches or thermostats (or giving customers their choice of technology).[26]
  - Aggressive enrollment of back-up generators in DR programs.

- Programs should be implemented which focus on achieving firm capacity reductions as this provides the highest value demand response. This is accomplished through establishing appropriate customer expectations and by conducting program tests for each DR program in each year. These tests should be used to establish expected DR program impacts when called and to work with customers each year to ensure that they can achieve the load reductions expected at each site.

- Customer education should be included in DR efforts. There is some perceived lack of customer awareness of programs and incentives. In addition, new programs will need marketing efforts as well as technical assistance to help customers identify where load reductions can be obtained and the technologies/actions needed to achieve these load reductions. Also, high-level education on the volatility of electricity markets helps customers understand why utilities and other entities are promoting DR and the customers' role in increasing demand response to help match up with supply-side resources to achieve lower cost resource solutions when markets become tight

- Increase clarity and coordination between the Federal and State agencies and programs. While states have primary jurisdiction over retail demand response, FERC has jurisdiction over demand response in wholesale markets. Greater clarity and coordination between the Federal and State programs is needed.

- Pricing should form the cornerstone of an efficient electric market. Daily TOU pricing and day-ahead hourly pricing will increase overall market efficiency by causing shifts in energy use from on-peak to off-peak hours every day of the year. However, this does not diminish the need to have dispatchable DR programs that can address those few days that represent extreme events where the highest demands occur. These events are best addressed by dispatchable DR programs.

MACROECONOMIC IMPACTS: THE DEEPER MODEL

Up to this point in the analysis we have examined the potential costs and benefits of implementing policies that might stimulate greater levels of energy efficiency and onsite solar energy in Pennsylvania. The evidence suggests that smart policies and programs can drive more productive investments in energy-efficient technologies, and they can do so in ways that reduce the state's total energy bill. But the question remains, what does this mean for the state economy? Do the higher gains in energy productivity – that is, do the increased levels of efficiency investment with their concomitant reduction in the need for conventional energy resources – create a net economic boost for Pennsylvania? Or, does the diversion of revenues away from energy-related industries negatively impact the economy? In this chapter, we explore those issues and we present the analytical results of an economic model used to evaluate the impact of efficiency investments on jobs, income, and the overall size of the economy.

A recent meta-review of some past 48 energy policy studies done within the United States suggests that if investments in more efficient technologies are cost-effective, the impacts on the economy should be small but net positive (Laitner and McKinney 2008). As shown elsewhere in the report, it turns out that from a total resource cost perspective, the benefits (i.e., the energy bill savings) outweigh both the policy costs and investments by about two and one-half times. In other words, the energy efficiency policy recommendations highlighted in the policy scenario result in a substantial savings for households and businesses compared to the costs of

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[26] This approach is currently being used successfully by LGE Energy.

implementing the policies. As we also discuss below, this consumer energy bill savings can drive a significant increase in the number of net new jobs within the Pennsylvania.[27] In fact, continued investments in energy efficiency resources would maintain the energy resource benefits for many years into the future, well beyond the period of analysis examined in this report.[28] The state therefore has the opportunity to transition its energy markets to a more sustainable pattern of energy production and consumption in ways that benefit consumers.

A quick glance at the results in Table 26 below, detail the benefits that will accrue to the state of Pennsylvania when policies encourage a more efficient use of energy resources. Further discussion in this section will provide an overview of the DEEPER model and more detailed background information for the state of Pennsylvania.

Table 26. Economic Impact of Energy Efficiency Investment in Pennsylvania

Macroeconomic Impacts	2010	2015	2020	2025
Jobs (Actual)	1,669	1,873	14,451	27,232
Wages (Million $2006)	$36	-$33	$442	$1,098
GSP (Million $2006)	$131	-$110	$1,021	$2,567

Methodology

The macroeconomic evaluation that we report in this chapter is undertaken in three separate steps. First, we calibrate ACEEE's economic assessment model called DEEPER (Dynamic Energy Efficiency Policy Evaluation Routine) to reflect the economic profile of the Pennsylvania economy (Laitner and McKinney 2009). This is done for the period 2006 (the base year of the model) through 2025 (the last year of the analysis). In this respect, we incorporate the anticipated investment and spending patterns that are suggested by the standard forecast modeling assumptions. These range from typical spending by businesses and households in the analytical period to the anticipated construction of new electric power plants and other energy-related spending that might also be highlighted in the forecast. Second, we transform the set of key efficiency scenario results from the policy analysis into the direct inputs which are needed for the economic model. The resulting inputs include such parameters as:

- The level of annual policy and/or program spending that drives the key policy scenario investments;
- The capital and operating costs associated with more energy-efficient technologies;
- The energy bill savings that result from the various energy efficiency policies described in the main body of the report; and
- Finally, a set of calibration or diagnostic model runs to check both the logic and the internal consistency of the modeling results.

So that we can more fully characterize the analysis that was completed for this report, we next provide a simplified working example of how the modeling is done. We first describe the financial assumptions that underpin the analysis. We then highlight the analytical technique by showing the kinds of calculations that are used and then summarize the overall results in terms of net job impacts. Following this example, we then review the net impacts of the various policies as evaluated in our DEEPER model.

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[27] As we use the term here, the word "consumer" refers to any one who buys and uses energy. Thus, we include both households and businesses as among the consumers who benefit from greater investments in energy efficiency.

[28] As we note elsewhere, the policy analysis ends in the year 2025. Yet, many of the investments we describe have a technology of perhaps 15 years. This means that investments made in 2025 would continue to pay for themselves through perhaps the year 2044 and beyond; and none of those ongoing energy bill savings are reflected in the analysis described in this chapter.

Illustrating the Methodology: Pennsylvania Jobs From Efficiency Gains

To illustrate how a job impact analysis might be done, we will use the simplified example of installing one hundred million dollars of efficiency improvements within large office buildings throughout Pennsylvania. Office buildings (traditionally large users of energy due to heating and air-conditioning loads, significant use of electronic office equipment, and the large numbers of persons employed and served) provide substantial opportunities for energy-saving investments. The results of this example are summarized in Table 27.

The assumption used in this example is that the investment has a positive benefit-cost ratio of 2.0. In other words, the assumption is that for every dollar of cost used to increase a building's overall energy efficiency, the upgrades might be expected to return a total of two dollars in reduced electricity and natural gas costs over the useful life of the technologies. This ratio is similar to those cited elsewhere in this report. At the same time, if we anticipate that the efficiency changes will have an expected life of roughly 15 years, then we can establish a 15-year period of analysis. In this illustration, we further assume that the efficiency upgrades take place in the first year of the analysis, while the electricity bill savings occur in years one through 15.

Table 27. Illustrative Example: Job Impacts from Commercial Building Efficiency Improvement

Expenditure Category	Amount (Million $)	Employment Coefficient	Job Impact
Installing Efficiency Improvements in Year One	$100	13	1,300
Diverting Expenditures to Fund Efficiency Improvements	$-100	12	-1,200
Energy Bill Savings in Years One through 15	$200	12	2,400
Lower Utility Revenues in Years One through 15	$-200	5	-1,000
Net 15-Year Change	$0.0		1,500

Note: The employment multipliers are adapted from the appropriate sector multipliers from IMPLAN. The benefit-cost ratio is assumed to be 2.0. The jobs impact is the result of multiplying the row change in expenditure by the row multiplier. The sum of these products yields a working estimate of total net job-years over the 15-year time horizon. To find the average annual net jobs in this simplified analysis we would divide the total job-years by 15 years which, of course, gives us an estimated net gain of 100 jobs per year for each of the 15 years. For more details, see the text that follows.

The analysis assumes that we are interested in the net effect of employment and other economic changes. This means we must first examine all changes in household and business expenditures – both positive and negative – that result from a movement toward greater levels of energy efficiency. Although more detailed and complicated within the DEEPER model, for this heuristic exercise we then multiply each change in expenditures by the appropriate sector employment coefficient (adapted from IMPLAN). The sum of these products will then yield the net result for which we are looking.

In our example above, there are four separate changes in expenditures, each with their separate impact. As Table 27 indicates, the net impact of the scenario suggests a cumulative gain of

1,500 jobs in each of the 15-year period of analysis. This translates into an average net increase of 100 jobs each year for 15 years. In other words, the $100 million efficiency investment made in Pennsylvania's office buildings is projected to sustain an average of 100 jobs each year over a 15-year period compared to a "business-as-usual" scenario.

The economic assessment of the alternative energy scenarios was carried out in a very similar manner as the example described above. That is, the changes in energy expenditures brought about by investments in energy efficiency and renewable technologies were matched with their appropriate employment multipliers. There are several modifications to this technique, however.

First, it was assumed that only 72 percent of both the efficiency investments and the savings are spent within Pennsylvania. We based this initial value on the Minnesota IMPLAN Group, Inc. (IMPLAN 2008) dataset as it describes local purchase patterns that typically now occur in the state. We anticipate that this is a conservative assumption since most efficiency and renewable energy installations are likely (or could be) carried out by local contractors and dealers. If the set of policies encourages greater local participation so that the share was increased to 90 percent, for example, the net jobs might grow another 15 percent compared to our standard scenario exercise. At the same time, the scenario also assumes Pennsylvania provides only 40 percent of the manufactured products consumed within the state. But again, a concerted effort to build manufacturing capacity for the set of clean energy technologies would increase the benefits from developing a broader in-state energy efficiency and renewable energy manufacturing capability.

Second, an adjustment in the employment impacts was made to account for assumed future changes in labor productivity. As outlined in the Bureau of Labor Statistics Outlook 2006–2016, productivity rates are expected to vary widely among sectors (BLS 2006). For instance, drawing from the BLS data we would expect that electric utilities might increase labor productivity by 1.8 percent annually while the business and personal service sectors of the economy might increase productivity by 2.2 percent per year. This means, for example, that we might expect a one million dollar expenditure for utility services in the year 2025 would support only 68 percent of the jobs that the same expenditure would have supported in 2008, while other services sectors of the economy would support only 62 percent of the jobs as in 2008.

Third, for purposes of estimating energy bill savings, it was assumed that all energy prices within Pennsylvania would follow the same growth rate as those published by the Energy Information Administration in its *Annual Energy Outlook* (EIA 2008b). Fourth, it was assumed that approximately 80 percent of the efficiency investments' upgrades are financed by bank loans that carry an average eight percent interest rate over a five-year period. To limit the scope of the analysis, however, no parameters were established to account for any changes in interest rates as less capital-intensive technologies (i.e., efficiency investments) are substituted for conventional supply strategies, or in labor participation rates – all of which might affect overall spending patterns. Fortunately, however, it is unlikely that these sensitivities would greatly impact the overall outcome of this analysis.

While the higher cost premiums associated with the energy efficiency investments might be expected to drive up the level of borrowing (in the short term), and therefore interest rates, this upward pressure would be offset to some degree by the investment avoided in new power plant capacity, exploratory well drilling, and new pipelines. Similarly, while an increase in demand for labor would tend to increase the overall level of wages (and thus lessen economic activity), the job benefits are small compared to the current level of unemployment or underemployment in the state. Hence the effect would be negligible.

Fifth, as described in the previous chapters for the buildings, industrial, and transportation end-use sectors it was assumed that a program and marketing expenditure would be required to promote market penetration of the efficiency improvements. Since these vary significantly by policy bundle we don't summarize them here but payment for these policy and program expenditures were treated as if new taxes were levied on the state commensurate with the level of energy demands within the state. Hence, the positive program spending impacts are offset by reduced revenues elsewhere in the economy.

Sixth, it should be noted that the full effects of the efficiency investments are not accounted for since the savings beyond 2025 are not incorporated in the analysis. Nor does the analysis include other benefits and costs that can stem from the efficiency investments. Non-energy benefits can include increased worker productivity, comfort and safety, and water savings, while non-energy costs can include aesthetic issues associated with compact fluorescent lamps and increased maintenance costs due to a lack of familiarity with new energy-efficiency equipment (NAPEE 2007b, 3-8). Productivity benefits, for example, can be substantial, especially in the industrial sector. Industrial investments that increase energy efficiency often result in achieving other economic goals such as improved product quality, lower capital and operating costs, increased employee productivity, or capturing specialized product markets (see, for example, Worrell et al. 2003). To the extent these "co-benefits" exceed any non-energy costs, the economic impacts of an energy efficiency initiative in Pennsylvania would be more favorable than those reported here. Finally, although we show how the calculations would look from an employment perspective, we don't show the same kind of data or assumptions for either income or for impacts on the Gross State Product (the sum of value-added contributions to the Pennsylvania State economy). Nonetheless, the approach is very similar to that described for net job impacts.

Impacts of Recommended Energy Efficiency Policies

For each year in the analytical period, the given change in a sector spending pattern (relative to the reference scenario) was matched to the appropriate sectoral impact coefficients. Two points are worth special note: first, it was important to match the right change in spending to the right sector of the Pennsylvania economy; and second, these coefficients change over time. For example, labor productivity changes mean that there may be fewer jobs supported by a one million dollar expenditure today compared to that same level of spending in 2025. Both the negative and positive impacts were summed to generate the estimated net results shown in the series of tables that follow. Presented here are two basic sets of macroeconomic impacts for the benchmark years of 2010, 2015, 2020, and 2025. These include the financial flows that result from the policies described in the previous chapters. They also include the net jobs, income, and GRP impacts that result from the changed investment and spending patterns.

Table 28 presents the changes in consumer expenditures that result from these policies. While the first row in the table presents the full cost of the energy efficiency policies, programs and investments, the utility customers will likely borrow a portion of the money to pay for these investments. Thus, "annual consumer outlays," estimated at about $366 million 2010, rise to nearly $2.4 billion in 2025. These outlays include actual "out-of-pocket" spending for programs and investments, along with money borrowed to underwrite the larger technology investments. The annual energy bill savings reported in Table 28 are a function of reduced energy purchases from the many Pennsylvanian utilities and other energy providers within the state.

As we further highlight in the table that follows, the annual energy bill savings begins with a modest first year benefit of $33 million. As more and more investments are directed toward the purchase of more energy-efficient technologies, the annual consumer energy bill savings rise to about $2.3 billion by 2025.

Table 28. Financial Impacts from Energy Efficiency Policy Scenario

(Millions of 2006 $)	2010	2015	2020	2025
Annual Consumer Outlays	$366	$1,387	$2,091	$2,491
Annual Energy Savings	$120	$2,154	$4,756	$7,242
Energy Bill Adjustment Savings	$33	$774	$1,666	$2,387
Annual Net Consumer Savings	-$213	$766	$2,665	$4,751
Cumulative Net Energy Savings	-$233	$1,018	$9,657	$29,327

‘Annual’ refers to the total that is reported in the benchmark year while ‘Cumulative’ is the total from previous years beginning in 2010 through the benchmark year.
Annual consumer outlays include administrative costs to run programs, incentives provided to consumers, investments in energy efficiency devices and interest paid on loans needed to underwrite the needed efficiency investments.
Annual energy savings is the reduced energy bill expenditures that benefit both households and businesses within a given year. The net savings is the difference between savings and outlays. The numbers in parentheses are losses in that specific year.

Readers should note from Table 28 that in the early years and especially as the policies ramp up quickly to stimulate a greater level of efficiency improvements, the consumer outlays outweigh the energy bill savings. In 2010, the net annual savings begin at -$213 million and rise to $766 million in 2015. But, early investments in energy efficiency improvements lead to greater, long-term savings for consumers. These savings mount steadily through the year 2025 by when they reach an estimated $4.7 billion net annual savings for the state as a whole. The last row of the table highlights cumulative impacts, which become positive in 2014 (not shown). By 2025, the net cumulative savings over the period 2010 through 2025 show a strong net positive result, reaching nearly $29 billion.

While the annual net consumer savings first turn positive in 2014 the simple payback period to participants is much shorter, ranging from 2.0 to 2.9 years depending on the year of participation between 2009 and 2025.

At this point we then have the financial flows estimated as they are distributed across the end-use sectors described earlier in the report. The question then becomes what might be the impacts on the state economy as we’ve been able to evaluate them for a given year using the DEEPER model. The modeling then evaluates impact on jobs and wages sector-by-sector, and evaluates their contribution to Pennsylvania’s Gross State Product (GSP), which is a sum of the net gain in value-added contributions provided by the energy productivity gains throughout all sectors of the state economy. As with the previous table on financial impacts, Table 29 highlights the net impacts for the benchmark years 2010, 2015, 2020 and 2025.

Table 29. Economic Impact of Energy Efficiency Investment in Pennsylvania

Macroeconomic Impacts	2010	2015	2020	2025
Jobs (Actual)	1,669	1,873	14,451	27,232
Wages (Million $2006)	$36	-$33	$442	$1,098
GSP (Million $2006)	$131	-$110	$1,021	$2,567

Given both the financial flows and the modeling framework, the analysis suggests a net contribution to the state's employment base as measured by full-time jobs equivalent. In the year 2010 we see a small net increase of 1,669 jobs which increases to a significantly larger total of 27,232 jobs by 2025. This significantly positive impact might seem to provide us with a counterintuitive result. The early years of the policy scenarios show small net cost to the economy. Yet we continue to see a net increase in jobs. How is this possible?

In Pennsylvania, the electric power and the natural gas service sectors directly and indirectly employ about 2.6 and 1.3 jobs, respectively, for every $1 million of spending. But, sectors vital to energy efficiency improvements like construction, utilize 7.8 jobs per $1 million of spending. Once job gains and losses are netted out in each year, the analysis suggests that, by diverting expenditures away from non-labor intensive energy sectors, the cost-effective energy policies can positively impact the larger Pennsylvanian economy – even in the early years, but especially in the later years of the analysis as the energy savings continue to mount.

To highlight the results of this analysis in a little more detail, Figure 29 provides year-by-year impacts on net jobs within Pennsylvania. Figure 30 highlights the anticipated net gain to the state's wage and salary compensation and Gross State Product, both measured in millions of 2006 dollars.

Figure 29. Net Job Impacts for Pennsylvania (2008-2025)

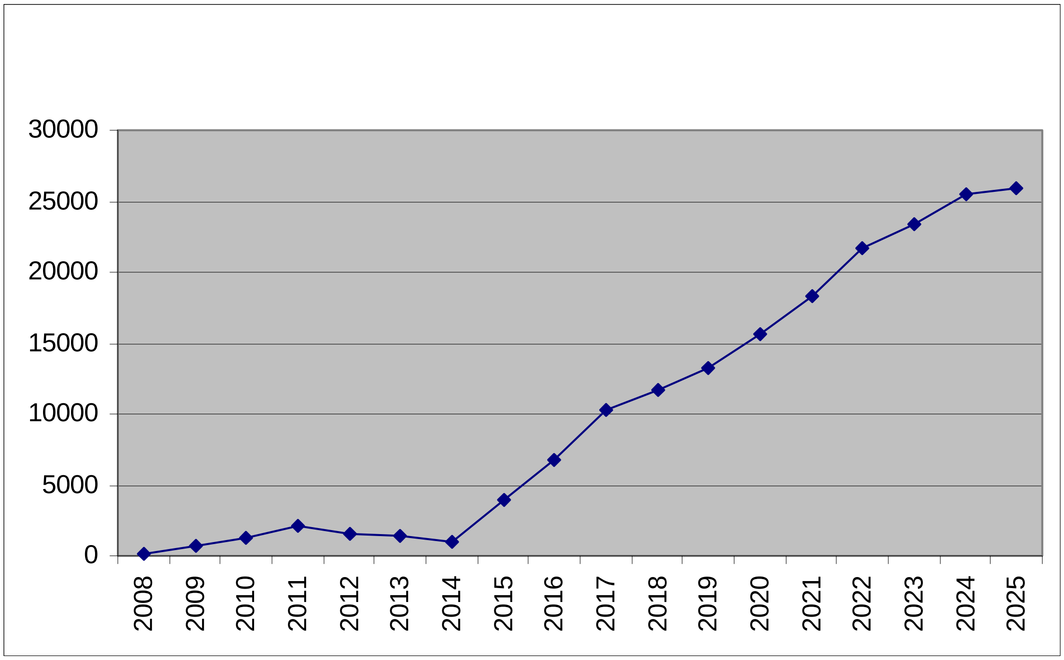
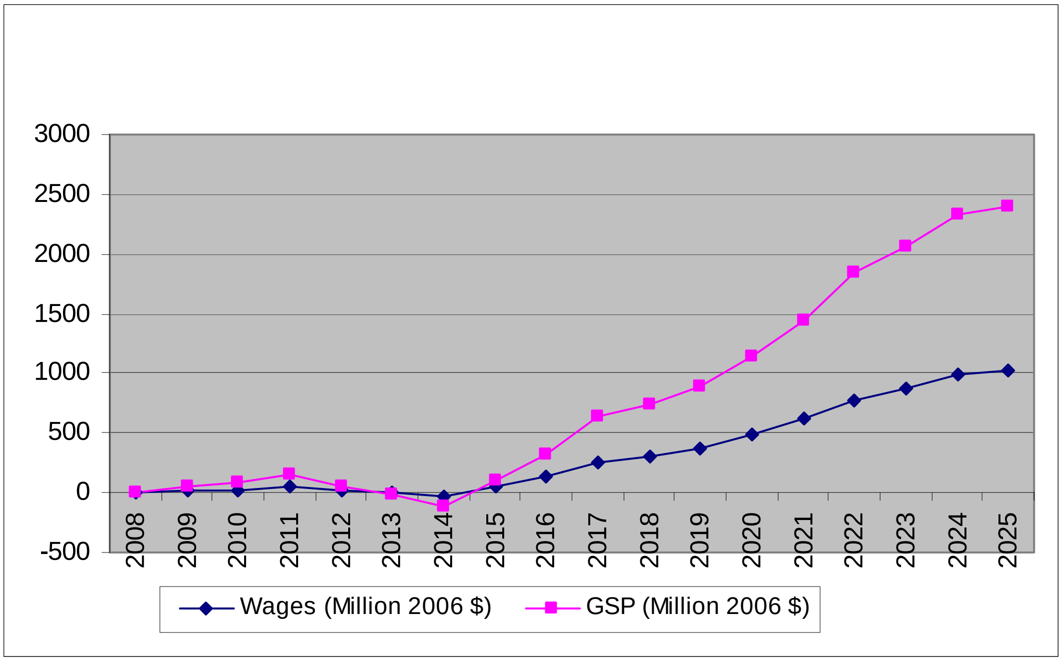


Figure 30. Wages and Gross State Product Impacts for Pennsylvania



The end result of this policy analysis, then, suggests that an early program stimulus which drives a higher level of efficiency investments can actually increase economic impact, creating an average of 1,590 net new jobs from 2010-2015, and rising to an estimated average of 17,513 net new jobs over the last decade of the analysis. This is roughly equivalent to the employment that would be directly and indirectly supported by the construction and operation of 217 small manufacturing plants within Pennsylvania. As indicated by Figure 30, these investments also increase both wages and Gross State Product throughout Pennsylvania.

In short, the more efficient use of energy resources provides a cost-effective redirection of spending away from less labor-intensive sectors into those sectors that provide a greater number of jobs within Pennsylvania. Similarly, cost-effective energy productivity gains also redirect spending away from sectors that provide a smaller rate of value-added into those sectors with slightly higher levels of value-added returns per dollar of revenue. The extent to which these benefits are realized will depend on the willingness of business and policy leaders to implement the recommendations that are at the heart of this report and found earlier in this assessment. It is also important to note that these results are not finalized. Several policy areas remain to be incorporated into the DEEPER model, including onsite solar. It is expected that if these policy results were to be incorporated into DEEPER, there would be a higher impact on job creation and GSP.

EMISSIONS IMPACTS IN POLICY SCENARIO

In 2006, emissions attributable to power generation in Pennsylvania alone were 138 million tons of CO2, 194 thousand tons of nitrogen oxides (NOx) and 923 thousands of sulfur dioxide (SO_2) (EIA 2007b). Current emissions from natural gas and oil consumption in the residential, commercial, and industrial sectors contribute another 47 million tons of CO2. In total, we estimate the baseline emissions in Pennsylvania from these sources to be 190 million tons CO2, which we define as the baseline reference case.

Electricity savings from Pennsylvania energy efficiency policies would have an impact across the Mid-Atlantic region due to the nature of the PJM wholesale market. Likewise, energy savings programs and policies for electricity undertaken in any of the other thirteen PJM states would have an impact on power generation in Pennsylvania. For illustrative purposes, we assume that all emissions reductions from electricity energy efficiency in Pennsylvania reduce in-state power generation emissions; and that there are no out-of-state efficiency impacts on in-state power generation.

We estimate that the energy efficiency and onsite solar policy scenario would save a total of about 40 million tons of carbon dioxide (CO_2) emissions in 2025 (see Appendix C for assumptions and methodology). Overall, the savings of 40 million tons of CO2 are equivalent to about a 22% reduction in the baseline emissions in Pennsylvania, which was defined as only emissions attributable to electricity generation and to natural gas and oil consumption in the residential, commercial, and industrial sectors.

DISCUSSION

The primary goals of this study were twofold: (1) to characterize the overall cost-effective energy efficiency resource potential in Pennsylvania; and (2) develop a suite of possible energy efficiency, onsite solar, and demand response policies for the Commonwealth and assess their energy and economic impacts. The results of the suggested policy suite are intended for state policy leaders, legislators, and regulators in developing high-level policies and regulations, while the results of the cost-effective resource assessment are intended to provide policy makers a level of confidence in the reasonableness of the suggested policy suite and its impacts. Readers should note that the resource assessment is not intended to provide detailed energy efficiency *program* plans that will be needed in the state. These analyses will be needed in the near future to design specific customer programs.

Results

Based on the findings of the overall cost-effective energy efficiency potential analysis, we estimate that nearly 30% of Pennsylvania's projected electricity, natural gas, fuel oil, and propane can be met through existing, cost-effective efficiency measures that are widely available today. We estimate that there is an economic potential for energy efficiency to meet about 61,000 GWh, or 33%, of Pennsylvania's electricity use in 2025, 174,000 BBtu, or 27%, of natural gas needs, and 320 million gallons of fuel oil, or 29% of the state's projected needs in 2025. And through new, emerging technologies, the cost-effective potential will continue to expand by 2025. Through specific policy actions, as outlined and assessed in the energy efficiency policy analysis and the onsite solar market potential assessment, we estimate that Pennsylvania can achieve 60-90% of the existing cost-effective efficiency resource.

Need for Data Collection

In preparing this report, ACEEE reached out to several stakeholders in Pennsylvania, including the PUC, electric distribution companies, energy professionals, and others, to both request available data and understand the current dynamics and issues that have emerged around energy efficiency. Through these discussions, it became clear that state-specific data needed to assess efficiency potential was extremely limited. This issue has arisen in other states we've worked with, and results largely from the movement in the 1990s toward utility restructuring, which not only resulted in the suspension of most energy efficiency utility programs, but also led to the termination of many energy data collection and market survey activities.

A sustained effort to achieve energy efficiency in Pennsylvania must include a serious effort by the state and utilities to identify data needs and follow through on data collection. A state agency such as the PUC or DEP should be designated as the energy data coordinator for the state, while all entities including utilities should work together to develop and implement a coordinated plan for collection of this information, which will be necessary to effectively design and evaluate the performance of energy efficiency programs. Data resources needed include appliance and equipment saturation surveys that characterize existing buildings, new construction baseline surveys, end-use load-shape studies, and measurement and verification studies which use common methodologies and reporting formats. Surveys could be done individually by each utility but through a coordinated effort, or perhaps a single survey with each utility on the steering committee and designing it to provide utility-specific breakdowns. By having a single entity with the responsibility and resources to collect and analyze energy data, the state will be able to better verify the results of programs and policies, and future analysts will have the necessary data to identify further opportunities for energy efficiency resources.

Workforce Development

Another topic that consistently arose with stakeholders is that of workforce. Energy efficiency is much more labor intensive than supply resources such as power plants and transmission lines, which are much more capital intensive. This effect is demonstrated in the results of our macroeconomic assessment, which estimates that the energy efficiency policy scenario will result in an additional 16,000 jobs compared to a business as usual scenario. And these “green collar” jobs are well-paying positions, including for example HVAC technicians and industrial engineers, and local jobs that cannot be outsourced. While energy efficiency creates this *demand* for new workers, it also calls for the needed *supply* in well-trained workers. A coordinated, statewide effort, or “workforce council,” should be established that identifies and provides a clearinghouse of the existing training and certification capabilities in Pennsylvania and also highlights the most critical needs for new, highly trained workers. The council, which could include utilities, state officials, universities, labor representatives, etc., should then carry forth new or expanded opportunities for the highest need training resources.

Economic Impacts

In addition to the positive benefits from net energy bill savings within the Commonwealth, our analysis shows that the energy efficiency and onsite solar policy scenario would also have positive impacts on net job creation, gross state product (GSP) and wages in Pennsylvania. Because energy efficiency is an investment in a more productive use of current and future energy resources, Pennsylvania’s economy can realize benefits throughout the analysis period and beyond. Over 27,000 net new jobs will be created in the final year of the analysis, but beyond the year 2025 further jobs will be created and wages will increase the overall amount of economic activity in the state.

Conclusions

In 2008, Pennsylvania took significant steps to lay down the groundwork for a cleaner and more reliable energy future. And the opportunities that lie ahead offer even greater solutions to the Commonwealth’s ailing economy, rising energy prices, and strained household budgets. The findings of the energy efficiency, demand response, and onsite solar analyses included in this report show that Pennsylvania has the opportunity to meet a significant share of its growing energy needs through demand-side resources, while benefiting its economy and environment. These strategies will reduce consumer energy bills by billions of dollars, create tens of thousands of new, in-state jobs, and shape a cleaner and more reliable energy future.

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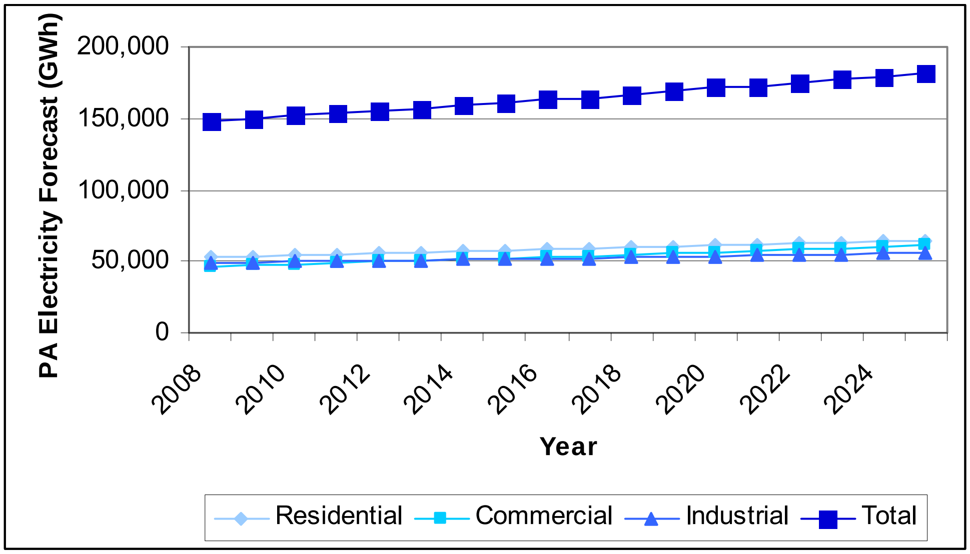
APPENDIX A – REFERENCE CASE

Projection of Pennsylvania Energy Consumption

Electricity (GWh) - Pennsylvania

To develop an electricity forecast, ACEEE begins with the Pennsylvania Public Utilities Commission's Forecast for the years 2000-2012 (PUC 2008b). After the year 2012, we extend the PUC's forecast to 2025 with a constrained growth rate from PJM's 2008 annual load forecast data (PJM 2008). We adjust PJM's forecast to include only those electric service territories that are in Pennsylvania to derive a weighted-average growth rate for Pennsylvania (PJM 2008). Sector-specific growth rates are then determined using the Annual Electricity Outlook for the mid-Atlantic region (EIA 2008). Using this methodology, ACEEE estimates that total electricity consumption in the state is projected to grow in the reference case at an average annual rate of 1.2% between 2008 (the analysis base year) and 2025, and 1.2%,1.6%, and 0.8% in the residential, commercial, and industrial sectors respectively. Actual electricity consumption in 2007 was 151,117 GWh (EIA 2008a), and in the reference case grows to 161,319 GWh by 2015 and 181,375 GWh by 2025.

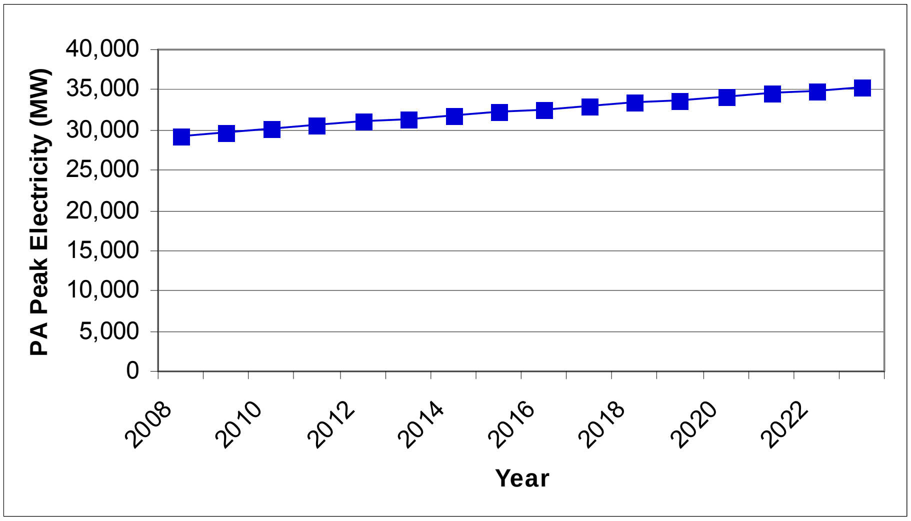
Figure A-1. Pennsylvania Electricity Consumption Forecast 2008-2025



Peak Demand Forecast

The peak demand forecast for the state began with the Pennsylvania PUC's peak demand forecast out to 2012 (PUC 2008b). We extend this forecast using PJM's peak demand load growth forecasts through 2023 for the entire PJM region, which were modified to obtain annual peak demand growth rates estimate specific for Pennsylvania (PJM 2008). To do this, we summed Allegheny Power, Duquesne, Metropolitan Edison, PECO, Pennsylvania Electric, PPL utilities' peak demand forecasts. Allegheny Power's service area spans into other states, so their peak demand forecast was modified to account only for the portion within Pennsylvania. The annual growth rate estimated from PJM's data was applied to the PUC forecast in order to obtain a forecast to 2023. Peak demand in Pennsylvania is forecasted to rise in the reference case at an average annual rate of 1.3% between 2008 (the analysis base year) and 2023. Peak demand in 2006 was 30,264 MW, and is forecasted to rise in the reference case to 32,227 MW by 2015 and 35,339 MW by 2023.

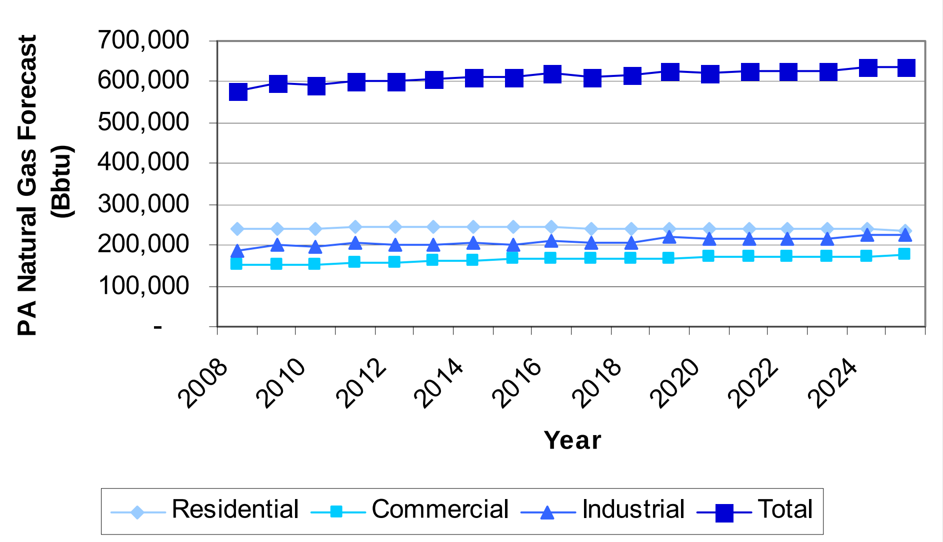
Figure A-2. Pennsylvania Peak Demand Forecast (MW) 2008-2023



Natural Gas Forecast – Pennsylvania

To develop a forecast of Pennsylvania's natural gas consumption, we begin with EIA's reported natural gas delivered to residential, commercial and industrial customers in the Commonwealth in 2007 (EIA 2007). Base values for the year 2007 are then projected to 2025 by applying natural gas consumption growth rates from EIA's *Annual Energy Outlook* for the Mid Atlantic (EIA 2008a). Using this methodology, total natural gas consumption in the state is projected to grow in the reference case at an average annual rate of 0.6% between 2008 (the analysis base year) and 2025, and -0.1%, 0.9%, and 1.2% in the residential, commercial, and industrial sectors, respectively. Actual natural gas consumption in 2007 for these sectors was 586,652 Bbtu (EIA 2007), and in the reference case grows to 609,537 BBtu by 2015 and 637,547 BBtu by 2025.

Figure A-3. Pennsylvania Natural Gas Consumption Forecast (2008-2025)

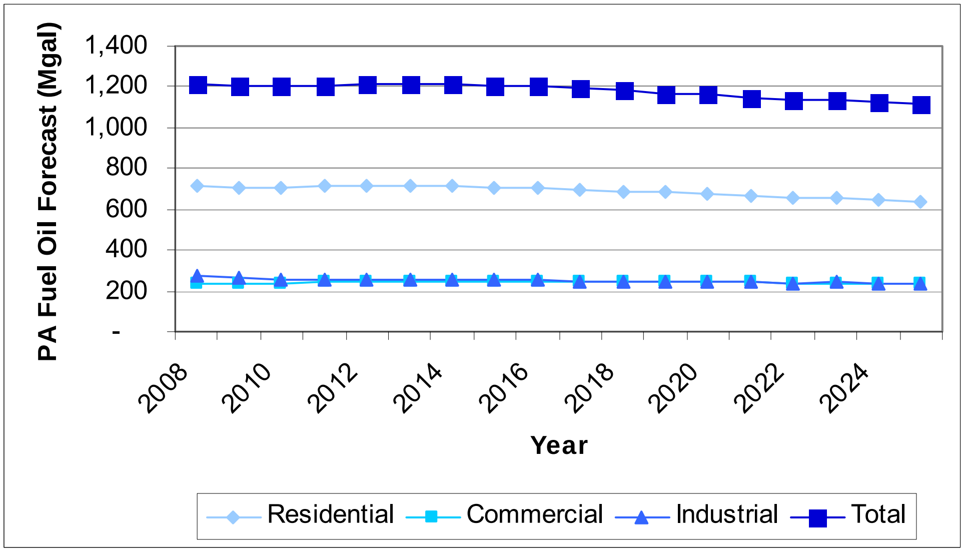


Fuel Oil Forecast – Pennsylvania

Pennsylvania's distillate fuel oil forecast begins with 2006 actual residential, commercial and industrial oil consumption from EIA's *Petroleum State Profiles* (EIA 2006a). The sectoral growth rates from

EIA's *Annual Energy Outlook* for the Mid Atlantic are then applied to 2006's actual consumption to obtain a forecast out to 2025 (EIA 2008a). Distillate fuel oil consumption in the state is projected to fall in the reference case at an average annual rate of -0.5% between 2008 (the analysis base year) and 2025, and change at -0.6%, 0.2%, and -0.8% in the residential, commercial, and industrial sectors respectively. Actual fuel oil consumption in 2006 was 1,256 Million gallons (MGal) (EIA 2006a), and in the reference case falls to 1,207 MGal by 2015 and 1,113 MGal by 2025.

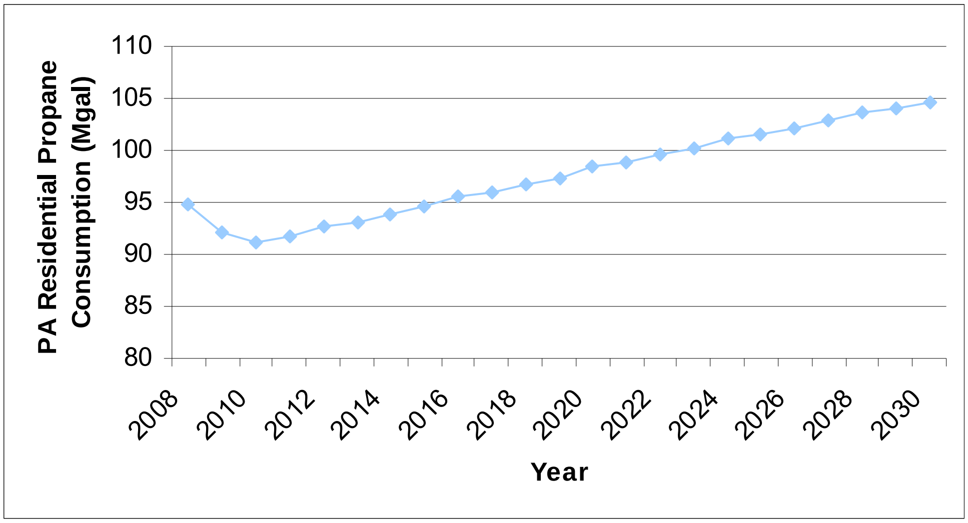
Figure A-4. Pennsylvania Distillate Fuel Oil Consumption Forecast 2008-2025



Residential Propane Forecast – Pennsylvania

Philadelphia's propane forecast begins with estimating 2005 propane consumption from the Residential Energy Consumption Survey (RECS) available through EIA. When combined with the number of households in Pennsylvania from Economy.com, RECS data detailing the percentage of all homes that use propane to heat their homes and gallon per household usage of propane provided residential baseline consumption of propane. A growth rate from EIA's Annual Energy Outlook was then applied to the 2005 baseline value to obtain a forecast to 2025. Between 2008 (the analysis base year) and 2025, residential propane consumption in the reference case is expected to increase 0.4%. Estimated residential propane consumption was at 94.9 Mgal in 2008 and 101.5 Mgal in 2025.

Figure A-5. Pennsylvania Residential Propane Consumption Forecast 2008-2025



Projection of Pittsburgh and Philadelphia Energy Consumption

Electricity Forecast – Pittsburgh[1]

The electricity forecast for Pittsburgh is developed using Pennsylvania electric utilities' 2007 annual reports available from the Pennsylvania PUC (PUC 2007a). These annual reports provide the number of customers served in each county of a utility's service area and the utility's total sales throughout the service area. We multiply the utility's total sales for residential, commercial and industrial consumers by the percentage of customers that reside within the counties of Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, and Westmoreland (Pittsburgh MSA) to obtain an estimate of 2007 sales within Pittsburgh. County lines and electric company service territories are show in Figure A-6. This methodology was performed for all utilities that have customers within Pittsburgh MSA (Duquesne Light Company, West Penn Power, Penn Power (MetEd/FirstEnergy), and Pennsylvania Electric Company) then totaled to obtain a 2007 base year for residential, commercial and industrial electricity consumption in Pittsburgh. Growth rates from PJM's annual load forecast data for Duquesne Light Company (which supplies nearly 90% of Pittsburgh's electricity) were applied to the base year to obtain projected electricity consumption to 2025 (PJM 2008). Pittsburgh electrical consumption in the state is projected to grow in the reference case at an average annual rate of 0.9% between 2008 (the analysis base year) and 2025. Actual electrical consumption in 2007 for these sectors was 15,964 GWh (PUC 2007a), and in the reference case grows to 17,213 GWh by 2015 and 18,755 GWh by 2025.

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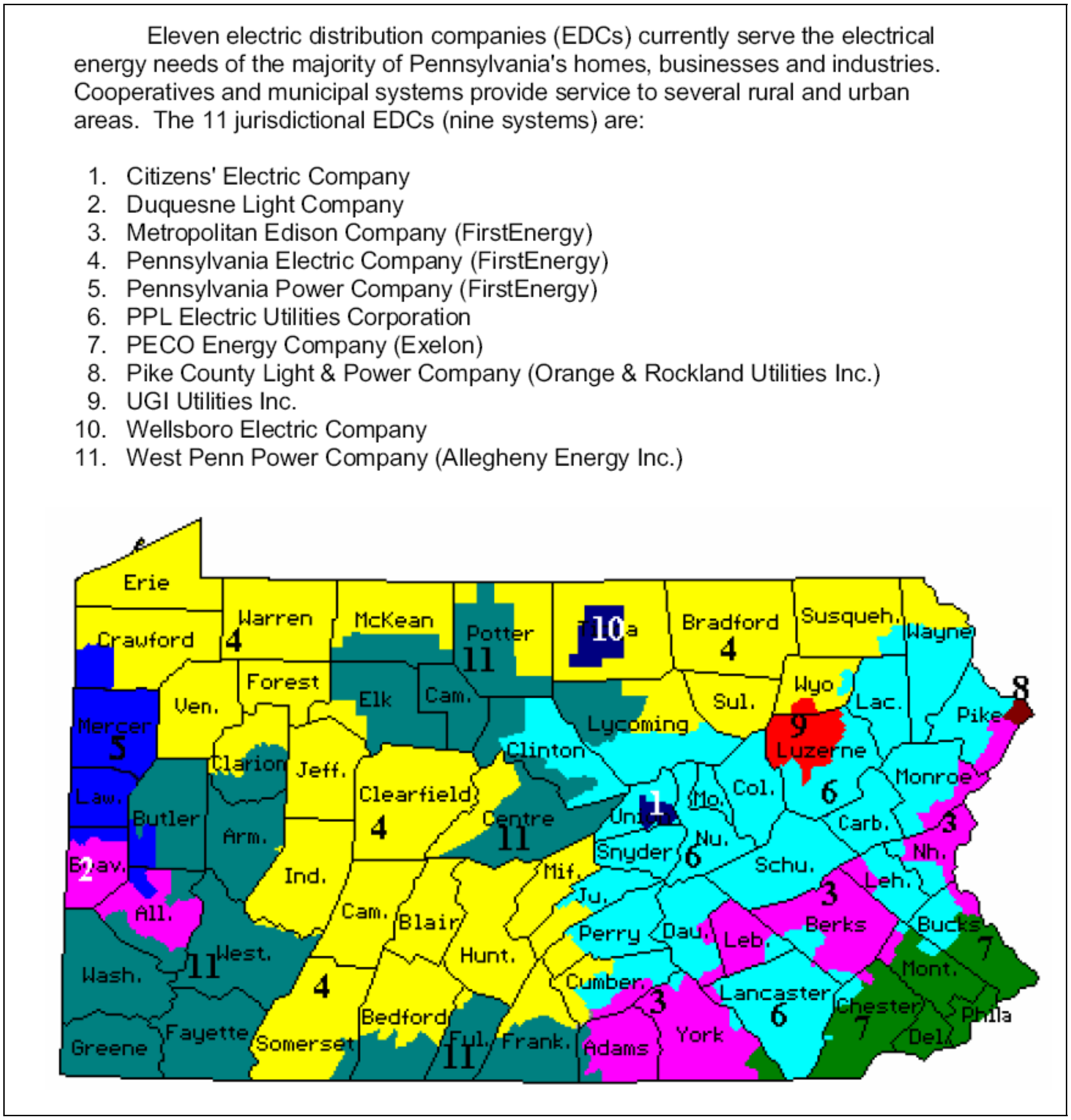
[1] For this analysis, Pittsburgh is defined as the Census Bureau's Metropolitan Area (MA) for the greater Pittsburgh area. The MA includes the counties of: Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, and Westmoreland.

Figure A-6. Pennsylvania Electric Distribution Company (EDC) Service Territories



Eleven electric distribution companies (EDCs) currently serve the electrical energy needs of the majority of Pennsylvania's homes, businesses and industries. Cooperatives and municipal systems provide service to several rural and urban areas. The 11 jurisdictional EDCs (nine systems) are:

1. Citizens' Electric Company
2. Duquesne Light Company
3. Metropolitan Edison Company (FirstEnergy)
4. Pennsylvania Electric Company (FirstEnergy)
5. Pennsylvania Power Company (FirstEnergy)
6. PPL Electric Utilities Corporation
7. PECO Energy Company (Exelon)
8. Pike County Light & Power Company (Orange & Rockland Utilities Inc.)
9. UGI Utilities Inc.
10. Wellsboro Electric Company
11. West Penn Power Company (Allegheny Energy Inc.)

Source: Pennsylvania PUC's *Electric Power Outlook.* (PUC 2008b)

Electricity Forecast – Philadelphia[2]

The electricity forecast for Philadelphia begins with an analysis of Pennsylvania's electrical utilities 2007 annual reports available from the Pennsylvania PUC (PUC 2007a). These annual reports detail the number of customers served in each county of a utility's service area and the utility's total sales throughout the service area. The utility's total sales for residential and combined commercial and industrial consumers (a few utilities in the Philadelphia MSA combine commercial and industrial consumers within their annual reports) is multiplied by the percentage of customers that reside within the counties of Bucks, Chester, Delaware, Montgomery, and Philadelphia to obtain an estimate of 2007 sales within the greater Philadelphia metro region. This methodology was performed across all utilities that have customers within this region (PECO Energy (Exelon), PPL Electric) then totaled to

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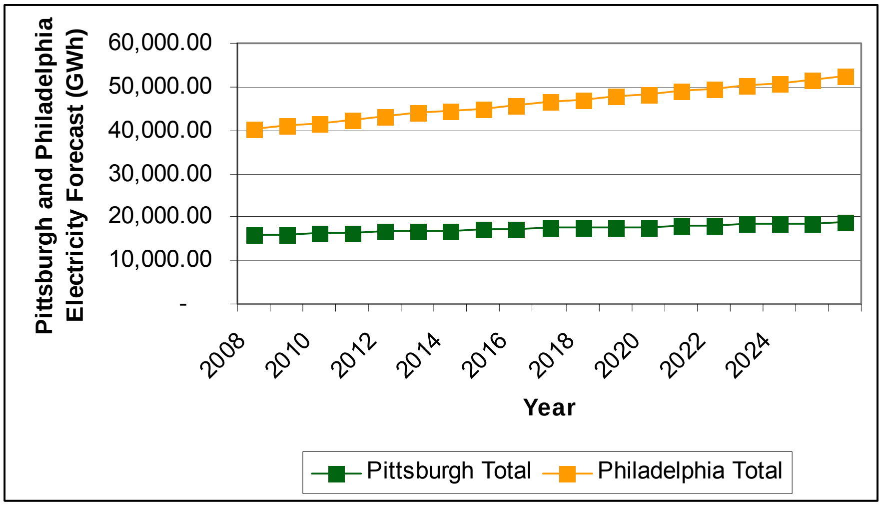
[2] Philadelphia is defined as the counties in the greater Philadelphia area, including: Bucks, Chester, Delaware, Montgomery, and Philadelphia.

obtain a 2007 base year for residential, commercial and industrial electricity consumption in Philadelphia. Growth rates from PJM's annual load forecast data for PECO Energy (which supplies 96% of Philadelphia 's electricity) were applied to the base year to obtain projected electricity consumption to 2025 (PJM 2008). Philadelphia electrical consumption in the state is projected to grow in the reference case at an average annual rate of 1.4% between 2008 (the analysis base year) and 2025. Actual electrical consumption in 2007 for these sectors was 40,433 GWh (PUC 2007a), and in the reference case grows to 45,739 GWh by 2015 and 52,427 GWh by 2025.

Figure A-7. Pittsburgh and Philadelphia's Electricity Consumption Forecast (2008-2025)



Natural Gas Forecast – Pittsburgh

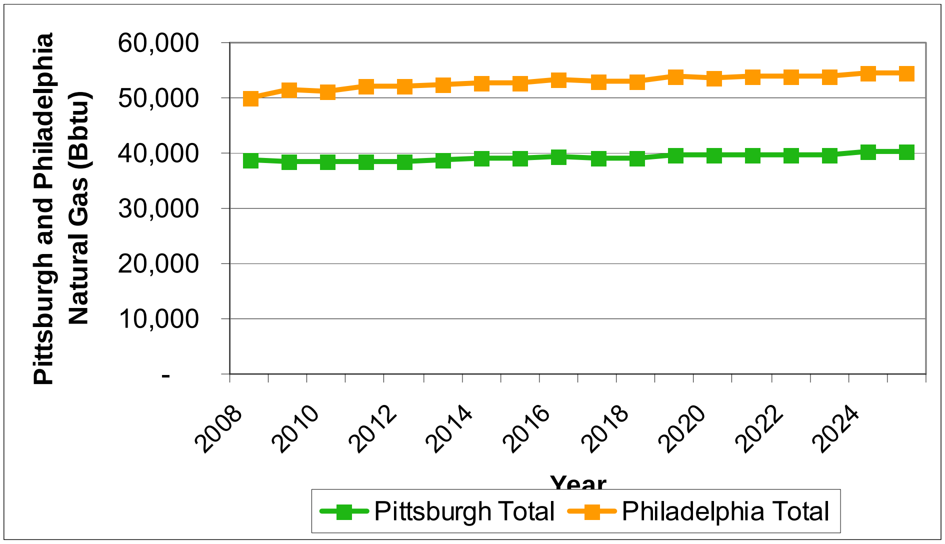
Similar to the regional electricity forecasts, the natural gas forecast for Pittsburgh begins with an analysis of Pennsylvania's natural gas utilities' 2007 annual reports (PUC 2007b). These annual reports provide the number of customers served in each county of a utility's service area and the utility's total gas deliveries throughout the service area. We multiply the utility's total deliveries for residential, commercial and industrial consumers by the percentage of customers that reside within the counties of the Pittsburgh region to obtain an estimate of 2007 natural gas deliveries. This methodology was performed for all utilities that have customers within the Pittsburgh MSA (Columbia Gas, Equitable Gas, Dominion Peoples, TW Philips, Herman Oil & Gas, National Fuel and Gas) then totaled to obtain a 2007 base year for residential, commercial and industrial natural gas consumption in Pittsburgh. Growth rates from EIA's *Annual Energy Outlook* for the Mid Atlantic (EIA 2008a) were applied to the base year to obtain projected natural gas consumption to 2025. Pittsburgh natural gas consumption in the state is projected to grow in the reference case at an average annual rate of 0.3% between 2008 (the analysis base year) and 2025, and -0.1%, 0.9%, and 1.2% in the residential, commercial, and industrial sectors respectively. Actual natural gas consumption in 2007 for these sectors was 39,815 BBtu (PUC 2007b), and in the reference case grows to 39,012 BBtu by 2015 and 40,203 BBtu by 2025.

Natural Gas Forecast – Philadelphia

The natural gas forecast for Philadelphia begins with an analysis of Pennsylvania's natural gas utilities 2007 annual reports available from the Pennsylvania PUC (PUC 2007b). These annual reports detail the number of customers served in each county of a utility's service area and the utility's total deliveries throughout the service area. The utility's total sales for residential and combined commercial and industrial consumers (a few utilities in the Philadelphia region combine commercial and industrial consumers within their annual reports) is multiplied by the percentage of customers that reside within the counties of the greater-Philadelphia region to obtain an estimate of 2007 natural gas deliveries. This methodology was performed for all utilities that have customers in Philadelphia

(Philadelphia Gas Works, PECO Energy, PPL Gas Utilities, and UGI Utilities) then totaled to obtain a 2007 base year for residential, and combined commercial and industrial natural gas consumption in Philadelphia. Growth rates from EIA's *Annual Energy Outlook* for the Mid Atlantic (EIA 2008a) were applied to the base year to obtain projected natural gas consumption to 2025. Philadelphia natural gas consumption in the state is projected to grow in the reference case at an average annual rate of 0.3% between 2008 (the analysis base year) and 2025, and -0.1%, and 1.1% in the residential and combined commercial and industrial sectors respectively. Actual natural gas consumption in 2007 for all sectors was 50,636 BBtu (PUC 2007b), and in the reference case grows to 52,702 BBtu by 2015 and 54,658 BBtu by 2025.

Figure A-8. Pittsburgh and Philadelphia's Natural Gas Consumption Forecast (2008-2025)



Fuel Oil Forecast – Pittsburgh

Pittsburgh's distillate fuel oil forecast begins with 2006 actual residential, commercial and industrial oil consumption for the state from EIA's *Petroleum State Profiles* (EIA 2006a). We then prorate this state forecast to Pittsburgh using county-level data from Economy.com. Household and population forecast data for the counties of Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, and Westmoreland (Pittsburgh MSA), was compared with household and population forecast data for the state as a whole to obtain a yearly percentage of households and population residing within the Pittsburgh MSA. The state's forecast for residential oil use utilizes the percentage of households within Pittsburgh to estimate the amount of residential oil use in Pittsburgh. The state's forecast for commercial and industrial oil use utilizes the percentage of population within the Pittsburgh MSA to estimate the amount of oil use in Pittsburgh's commercial and industrial sectors. We estimate a forecast by sector using EIA's *Annual Energy Outlook* for the Mid Atlantic and then applying it 2006's actual consumption out to 2025 (EIA 2008a).

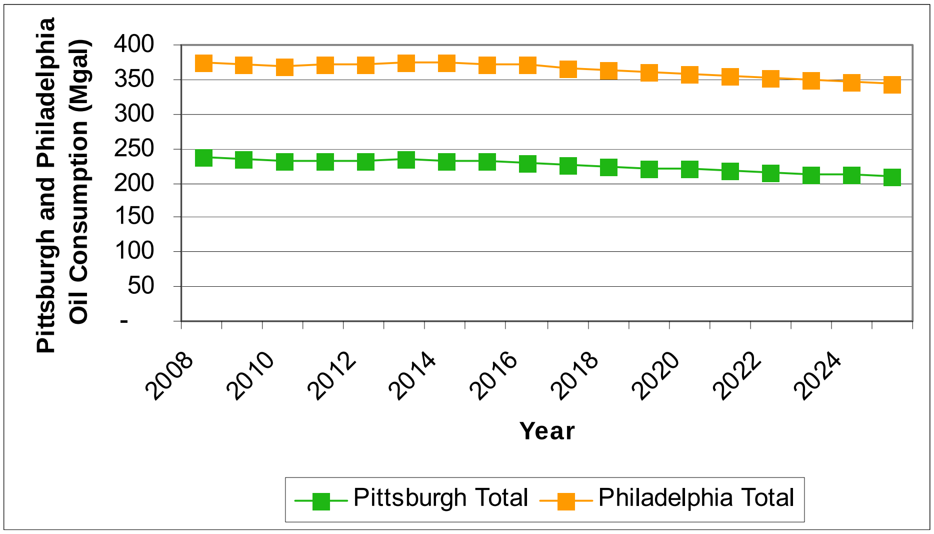
Distillate fuel oil consumption in Pittsburgh is projected to fall in the reference case at an average annual rate of -0.7% between 2008 (the analysis base year) and 2025, and fall at -0.8%, -0.1%, and -1.1% in the residential, commercial, and industrial sectors respectively. Estimated fuel oil consumption in 2006 was 247 MGal, and in the reference case falls to 231 MGal by 2015 and 209 MGal by 2025.

Fuel Oil Forecast – Philadelphia

Philadelphia's distillate fuel oil forecast begins with 2006 actual residential, commercial and industrial oil consumption for the state from EIA's *Petroleum State Profiles* (EIA 2006a). The sectoral growth rates from EIA's *Annual Energy Outlook* for the Mid Atlantic are then applied to 2006's actual consumption to obtain a forecast out to 2025 (EIA 2008a). This forecast for the state is then modified with county level data from Economy.com. Household and population forecast data for the counties of Allegheny, Allegheny, Armstrong, Bucks, Chester, Delaware, Montgomery, and Philadelphia (Philadelphia MSA), was compared with household and population forecast data for the state as a whole to obtain a yearly percentage of households and population residing within the Philadelphia MSA. The state's forecast for residential oil use utilizes the percentage of households within Philadelphia to estimate the amount of residential oil use in Philadelphia. The state's forecast for commercial and industrial oil use utilizes the percentage of population within the Philadelphia MSA to estimate the amount of oil use in Philadelphia's commercial and industrial sectors.

Distillate fuel oil consumption in Philadelphia is projected to fall in the reference case at an average annual rate of -0.5% between 2008 (the analysis base year) and 2025, and change at -0.6%, 0.2%, and -0.8% in the residential, commercial, and industrial sectors respectively. Estimated fuel oil consumption in 2006 was 387 MGal, and in the reference case falls to 372 MGal by 2015 and 344 MGal by 2025.

Figure A-9. Pittsburgh and Philadelphia Distillate Fuel Oil Consumption Forecast 2008-2025



Projection of Reference Case Supply Prices and Electricity Avoided Costs

Synapse Energy Economics developed projections of supply prices and avoided costs used in this study. These estimated were developed based on key input assumptions that were developed as part of the stakeholder engagement process. Synapse then developed a simplified Electricity Planning and Costing Model to develop the projections. This section describes the key inputs to the electricity model (Synapse electricity avoided cost model), the rationale for the proposed values and the sources of those values.

Caveats

The projected electricity supply prices and avoided costs reported in this memo are based upon a number of simplifying and conservative assumptions that we would not consider to be reasonable in other contexts. These include a simplified representation of avoided costs for different load factors and load shapes, and generic estimates of the capital costs of new resources.

Key Assumptions

This section describes the key inputs to the electricity model that Synapse Energy Economics has developed for this project (Synapse electricity cost model), the rationale for the proposed values and the sources of those values. The final inputs are based upon a set of draft inputs developed by Synapse[3] that ACEEE reviewed.

Input Assumptions

The key inputs to the electricity model are presented under the following thirteen categories:

- Basic Modeling assumptions
- Base year Sales and revenues
- Base year Load and resource Balance
- In-State Base Year Generation Resource Performance and Cost Data
- New Generation Resource Performance and Cost Data
- Fuel Types
- Annual Energy and Peak Load
- Capacity retirements
- Capacity additions
- Fuel prices
- Purchased Power Costs
- Carbon Emission Costs
- Wholesale Market Prices

Basic Modeling Assumptions

The base year is 2007. All monetary values are reported in constant 2006 year dollars unless noted otherwise. The study period begins in 2008 and ends in 2030, an analysis period of 23 years. The reporting period is 2009 through 2025, a total of 17 years. The financial parameters for costing resource additions are as follows:

- Inflation Rate. 2.50%. Rationale - the twenty year average (1987-2006) derived from the chained GDP deflator is 2.47%.
- Nominal Discount Rate. 10.0%. This represents the value for an independent power producer with a mix of equity and bond financing. Based on a 50/50 equity/debt mix with 12% for equity and 8% for debt. Used for levelization of capital expenditures. Actual rates for specific projects will vary depending on the nature of the project and the implementing entity.
- Real Discount Rate. 5.85%. Derived from the Nominal Discount Rate and the Inflation Rate.
- Income Tax Rate. Federal rate of 35% and PA state corporate rate of 9.99%. Property tax rate at the nominal level of 0.5% per annum of the initial plant cost (local rates vary considerably). Used for capital cost levelization.

Base Year Sales and Revenues

The historic sales and revenues data are obtained from the EIA's "State Electric Profile" Table 8 (http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html). This has been supplemented with data for 2007 from the EIA "Electric Power Monthly" report of March 2008 which contains data through December of 2007 (tables 5.4 and 5.5) (http://www.eia.doe.gov/cneaf/electricity/epm/epm_ex_bkis.html). The historic data indicates that

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[3] Deliverable 1 Input Assumptions for Electricity Cost Model, June 23, 2008.

Pennsylvania is net exporter and generates about 36% more electricity than it needs. Likewise the capacity in PA is substantially in excess of the in-state peak loads.

Base Year Load and Resource Balance

The historic sales and revenues data are obtained from the EIA's "State Electric Profile" Tables 5, 8 and 10 (http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html). This has been supplemented with data for 2007 from the EIA "Electric Power Monthly" report of March 2008 which contains data through December of 2007 (tables 1.6, 4.6, 4.20, 4.12 and 4.13) (http://www.eia.doe.gov/cneaf/electricity/epm/epm_ex_bkis.html).

In-State Base Year Generation Resource Performance and Cost Data

From the above EIA data, we have the generation, CO2 emissions and fuel costs for each generating group. From that we can derive the average heat rate for each group and the fuel component of the generation costs. To that we add typical industry values for O&M. Also from that EIA data we have the historic capacity factors associated with resource group. Those historic patterns are used to set the basis for future performance.

New Generation Resource Performance and Cost Data

For new generation resources we have used the technology parameters from the AEO 2008 Assumptions document. For capital costs we have used our professional judgment based on a number of sources to reflect current cost expectations for new construction.

Fuel Types

We use the three basic fuel types as specified in the EIA documents (Coal, Petroleum and Natural Gas) with the addition of nuclear and biomass.

Annual Energy and Peak Load

For energy and peak loads we have used the ACEEE Reference Case forecast of 10/7/08.

Capacity Retirements

There is very little information about future plant retirements and a variety of unknown circumstances may either work in favor of or against individual plants. It is however likely that some older less efficient generation will be retired in the future. To reflect this we are representing modest gradual retirement of existing resources in the model. But it is quite likely than many existing plants will be retrofitted and their lives extended.

Capacity Additions

In order to meet future load growth, new generation resources must be added to the existing generation mix. The electricity model is not a capacity expansion model that optimizes capacity additions by choosing among a set of resource alternatives to develop a least cost expansion plan. Instead, we add new resources "manually" to meet reserve needs. Our analysis considers three sets of additions:

- Planned Additions—Near-term proposed new additions or uprates to existing plants that are in development or advanced stages of permitting and have a high likelihood of reaching commercial operation;

- Mandatory Renewable Additions—Renewable generators that are added to meet existing or anticipated mandatory renewable portfolio standards (RPS) in each state. In Pennsylvania these are referred to as alternative energy resources (AERS); and,
- Generic Additions—New generic conventional resources that are added to meet the residual capacity need after adding planned and RPS additions.
- *Planned Additions*

***Description**:* Our near-term entry forecast is based on the types of projects in the PJM queue. Looking at the 2010-2013 period for PA and excluding the problematic nuclear plant in 2013, the mix is about 80% natural gas, 15% coal and 5% for a mix of various other types. Note too that the RPS requirements as discussed below do not appear to all be in the queue.

***Data Sources**:* PJM Interconnection Queue Requests.

Renewable Resource Additions

The PA Act 213 establishes Alternative Energy Portfolio Standards (AEPS) that require annually increasing percentages of electricity sold to retail customers be derived from alternative energy resources. There are two categories Tier 1 and Tier 2. Tier 1 resources include solar, wind, low-impact hydropower, geothermal, biologically derived methane gas, fuel cells, biomass and coal mine methane. Tier 2 resources include waste coal, demand side management, distributed generation, large-scale hydropower, by-products of wood-pulping and wood manufacturing, municipal solid waste and integrated combined coal gasification technology.[4] Tier 1 requirements gradually increase to 8% in 2021 while Tier 2 requirements increase in steps to 10% in the same year. In addition solar PV a subset of Tier 1 reaches a 0.5% level in 2021. The specific mix of these resources is not known, but we have assumed for Tier 1 (less the solar PV) that 90% of the energy will come from wind and 10% from biomass. For Tier 2 we understand that waste coal currently dominates and we project that that will remain much the same. However DSM could become the predominate future source. The operating characteristics are based on AEO 2008 and Synapse estimates based on experience elsewhere in the US.

Generic Additions

In order to reliably serve the forecasted load in the mid- to long-term portion of the forecast period, new generic additions will need to be added to the model. A range of generation technologies was initially considered for this purpose, including gas/oil-fired combined-cycle, gas/oil combustion turbines, conventional coal, and nuclear. We use the mix represented in the PJM Interconnection Queue as the guide.

Generic additions based on requirements after the RPS additions specified above are based on meeting a system-wide reserve goal. For these generic additions we use a mix of 15% conventional coal, 45% NGCC and 40% gas peaking units.

Fuel Prices

We start with fuel prices reported for the base year of 2007. We used several sources to reflect current prices through mid 2008, and expectations for the future.

- For natural gas our projection of wholesale prices in Pennsylvania for the next twelve years is equal to the Henry Hub price per the NYMEX futures as of November 13, 2008 plus a basis differential based on the state and Henry Hub prices in the reference year. After that point we apply the relative price trends from the AEO 2008 modeling.
- Petroleum prices are set at a historically determined multiple of natural gas prices.

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[4] Page 10, "Electric Power Outlook for Pennsylvania 2007-2012", Pennsylvania PUC, August 2008.

- For coal we use the reported base year cost scaled by the relative year to year changes from AEO 2008.

Power Purchase and Sale Prices

Since PA operates within the PJM deregulated market there is little specific information about the actual revenues associated with energy purchases and sales. As a proxy we have used the PJM Western Hub 2007 all-hours average prices as a reference point and scaled that with future trends of in-state production costs, as we have done for the regulated states. This is an approximation that reflects general behavior, but does not capture the details of any specific purchase and sale agreements.

Carbon Emission Costs

Carbon compliance costs are set at the Synapse 2008 mid-case level (see "Synapse 2008 CO2 Price Forecasts", July 2008, David Schlissel et al).

Wholesale Market Prices

Since PA operates within the deregulated PJM market, the wholesale prices of electric energy and capacity acquired to serve the retail market will be set based upon the operation of those markets rather than upon cost of service regulated production costs. In addition, the value of reductions in demand and/or annual energy, i.e., avoided costs, will reflect the process in those markets.

For energy prices we start with the all-hours futures prices, as of 11/13/08, for the PJM Western Hub for each year through 2012. These futures are traded on NYMEX. Then, we use the annual average 2007 PJM Locational Market Prices (LMP) reported for locations throughout PA, and the corresponding 2007 loads at those locations, to calculate an adjustment factor to apply to the PJM Western Hub prices in order to develop load-weighted equivalent annual energy prices for the entire state.

For capacity prices we use the RTO prices from the PJM RPM auction which are available by year through 2012.

We estimate total market-based avoided costs by adding the capacity price to the energy price, assuming that capacity costs are recovered at the historic annual system load factor.[5]

Reference Case Electricity Supply Prices and Avoided Electricity Costs

This section presents the projections of Reference Case electricity supply prices and avoided costs for Pennsylvania. This set of projections reflects an updated forecast of natural gas and electricity prices based on market conditions as of mid-November, 2008. The projections are outputs from the electricity costing model that Synapse Energy Economics has developed for this project. Readers should note that the projected electricity supply prices and avoided costs reported in this memo are based upon a number of simplifying and conservative assumptions that Synapse Energy Economics would not consider to be reasonable in other contexts. These include a simplified representation of avoided costs for different load factors and load shapes, and generic estimates of the capital costs of new resources.

The reference case load forecast, supply forecast, and supply prices are presented in Table A-1 below. The forecast of physical supply exceeds the forecast of physical load by the level of estimated losses in transmission and distribution. The supply prices consist of the projected wholesale electricity supply costs each year, the retail margin (calculated from the base year costs and retail

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[5] "System Load Factor" value in section "3 Base Year Load and Resource Balance" of the input data sheet.

prices) and the resulting total average retail rate. Note that the retail margin likely will change in future years because of a variety of economic and regulatory factors, and thus the retail rate forecast trends only reflect the energy supply costs.

The reference case avoided costs are presented in Table A-2. The avoided capacity costs are presented in $/kw-year while the avoided electric energy costs are given in ¢/kwh.

Table A-1. Pennsylvania Reference Case Load and Supply Forecast and Supply Prices

All costs in constant 2006 dollars.																		
CASE:	**PA Reference Case v2 - 11/25/08**																	
Category	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Load Forecast																		
Retail Energy	GWh	155,918	157,774	159,678	161,794	163,243	165,390	167,404	169,911	169,836	173,412	175,258	177,940	178,979	181,638	183,659	185,923	188,217
Retail Demand	MW	31,281	31,653	32,035	32,460	32,751	33,181	33,585	34,088	34,073	34,791	35,161	35,699	35,908	36,441	36,847	37,301	37,761
Supply Forecast																		
Capacity Requirement	MW	39,604	40,076	40,559	41,097	41,465	42,010	42,522	43,159	43,140	44,048	44,517	45,198	45,462	46,138	46,651	47,226	47,809
Capacity Sources																		
In-State Capacity	MW	45,142	45,320	46,325	46,039	46,937	48,392	48,598	49,940	49,211	50,300	51,150	51,646	53,008	52,425	53,818	54,040	54,956
Out-of-State Capacity	MW	-5,537	-5,244	-5,765	-4,942	-5,472	-6,382	-6,076	-6,782	-6,071	-6,252	-6,633	-6,447	-7,546	-6,287	-7,167	-6,814	-7,148
Total Capacity Provided	MW	39,604	40,076	40,559	41,097	41,465	42,010	42,522	43,159	43,140	44,048	44,517	45,198	45,462	46,138	46,651	47,226	47,809
Energy Requirement	GWh	171,657	173,701	175,797	178,126	179,722	182,086	184,303	187,063	186,981	190,917	192,950	195,902	197,046	199,974	202,199	204,691	207,216
Energy Sources																		
In-State Generation	GWh	228,618	230,008	236,129	235,902	239,968	247,206	249,223	257,489	255,484	261,437	266,234	269,669	277,972	277,045	284,344	286,771	292,086
Out-of-State Generation	GWh	-56,961	-56,308	-60,332	-57,775	-60,246	-65,120	-64,921	-70,426	-68,503	-70,520	-73,284	-73,767	-80,926	-77,071	-82,145	-82,080	-84,870
Total Energy Provided	GWh	171,657	173,701	175,797	178,126	179,722	182,086	184,303	187,063	186,981	190,917	192,950	195,902	197,046	199,974	202,199	204,691	207,216
Supply Price Forecast																		
Average Production Cost	¢/kWh	5.98	6.08	6.16	6.15	7.03	7.20	7.35	7.54	7.65	7.81	7.95	8.08	8.23	8.36	8.52	8.66	8.82
Retail Margin	¢/kWh	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92
Average Retail Rate	¢/kWh	8.90	9.00	9.07	9.07	9.95	10.11	10.27	10.46	10.57	10.72	10.86	11.00	11.15	11.28	11.44	11.58	11.74

Table A-2. Projections of Avoided Electricity Costs in Reference Case

All costs in constant 2006 dollars.

CASE: **PA Reference Case v2 - 11/25/08**

Category	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Avoided Costs by costing period																		
Avoided Resource Cost	¢/kWh	6.47	6.95	6.83	7.06	7.68	8.58	8.74	8.90	9.00	9.09	9.17	9.27	9.36	9.51	9.64	9.78	9.95
Avoided Capacity Cost	$/kW-yr	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11
	¢/kWh	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Avoided Energy Only Cost	¢/kWh	4.94	5.43	5.30	5.53	6.15	7.06	7.21	7.38	7.47	7.56	7.65	7.74	7.83	7.98	8.11	8.26	8.42

Notes: Avoided Resource Costs represent avoided production costs (fuel, O&M, CO2) for all resources, plus levelized capital costs for new resources.
Avoided Capacity Cost in $/kw-yr is converted into an energy cost equivalent (c/kWh) using the system load factor.
Avoided Energy Cost represents Total Avoided Resource Cost less Avoided Capacity Cost expressed as energy cost equivalent.

APPENDIX B – ENERGY EFFICIENCY RESOURCE ASSESSMENT

Residential Buildings Sector

Overview of Approach

Our analysis of energy efficiency potential for Pennsylvania's residential electricity, natural gas, fuel oil, and propane sectors considered a scenario with widespread adoption of cost-effective energy efficiency measures during the 18-year period from 2008 to 2025. We analyzed thirty-six single family measures and fourteen multifamily electricity measures. For natural gas efficiency, we analyzed twenty-five single family measures and twenty-two multifamily measures for existing residential buildings in Pennsylvania. And finally for fuel oil we analyzed twenty-five single family measures and nineteen multifamily measures and for propane we examine twelve single-family measures. These measures are grouped by end-use (heating and cooling loads, water heating, appliances, etc.) and measures for new residential buildings (see Tables B-1 through B-6). For each measure, we estimated average measure lifetime, electricity savings (kWh for electricity, MMbtu for natural gas, and million gallons for fuel oil) and costs per home upon replacement of the product or retrofitting of the measure. For a replacement-on-burnout measure,[6] the cost is the incremental cost of the efficient technology compared to the baseline technology. For retrofit measures, where existing equipment is not being replaced, such as improved insulation and infiltration reduction, the cost is the full installation cost of the measure. For measures modeled as replacement-on-burnout, the baseline is set according to the current market for that product, so the baseline efficiency is the minimum efficiency standard of that product. For measures modeled as retrofit, the baseline efficiency is that of estimated energy use in existing Pennsylvania homes.

A measure is determined to be cost-effective if its levelized cost of saved energy (CSE), which discounts the incremental cost of a measure over its lifetime, is less than $12.35/kWh for electricity, $14.34/MMbtu for natural gas, or $2.04/gallon for fuel oil, the current average residential costs in Pennsylvania (EIA 2008b). Estimated levelized costs for each efficiency measure, which assume a discount rate of 5%, are shown in Tables B-1 through B-6. Equation one shows the calculation for cost of conserved energy.

Equation 1. CSE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure (kWh/MMbtu/gallons))

Existing Buildings

To estimate the efficiency resource potential in existing homes in Pennsylvania by 2025, we first adjusted individual measure savings by an *Adjustment Factor*. This factor accounts for the technical feasibility of efficiency measures (the percent of Pennsylvania homes that satisfy the base case conditions and other technical prerequisites such as number of household members, heating fuel type, etc.) and the current market share of products that already meet the efficiency criteria. These assumptions are made explicit in Tables B-1 through B-6.

We then adjusted savings from the improved building envelope (insulation, windows, infiltration reduction, and duct sealing) to account for the reduced heating and cooling loads imparted by each of the envelope measures. Then we adjusted HVAC equipment savings to account for savings already realized from the reduced loads. Similarly, we adjusted water heating equipment savings to account for reduced water heating loads from the use of more efficient clothes washers, low-flow shower heads, water heater pipe insulation, and faucet aerators. The multiplier for these adjustments is called the *Interaction Factor.*

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[6] In a replacement-on-burnout scenario, a consumer purchases the more efficient product at the time of replacement of that product.

We then adjusted replacement measures with lifetimes more than 17 years to only account for the percent turning over in 17 years, which represents the time period of the analysis. Note that the multiplier, *Percent Turnover,* is only applicable to products being replaced upon burnout and not retrofit measures such as insulation and duct sealing and testing. These retrofit measures therefore have 100% of measures “turning over.”

Equation 2 shows our calculation for efficiency resource potential, incorporating the three factors discussed above:

Equation 2. Efficiency Resource Potential = ∑ (Annual Savings per Measure (kWh/MMbtu/gallons)) x (Percent Turnover) x (Adjustment Factor) x (Interaction Factor)

To calculate the efficiency resource potential savings by end-use in 2025, we present the savings as a percent of end-use energy consumption (assuming current energy consumption by end-use from AEO 2007). For the non-HVAC savings, we then multiply the “% savings” by projected residential energy consumption for that end-use in 2025 to estimate the total savings potential in that year (see Equation 2). We assume that savings in the residential new construction sector cover projected new HVAC consumption, and therefore multiply the HVAC “% savings” by 2008 electricity consumption of this end use. See Equation 3 for a summary of how we derive the savings estimate for existing residential buildings.

Equation 3. Efficiency Resource Potential by end-use in 2025 (GWh/MMbtu/Mgal) = (% End-Use Savings) x (Electricity Consumption by sector in 2025* (GWh/MMbtu/Mgal))
* 2008 for HVAC

New Construction

We estimate savings from new construction in a similar manner as existing home measures. We looked at three levels of efficiency in new homes: 15%, 30%, and 50% better than current energy code. In estimating new home energy savings, we use a similar approach as building codes, which address HVAC consumption only. We estimated *% Applicable* by allocating each home into one of the three bins, with 15% predominating the early years and 50% the later years. See Equation four for a summary of how we calculate savings in new construction.

Equation 4. Efficiency Resource Potential in 2025 (GWh/MMbtu/Mgal) = (% HVAC savings per home) x (Percent Applicable) x (Projected new HVAC consumption between 2008 and 2025 (GWh/MMbtu/Mgal)).

Electricity

Table B-1. Residential Single Family Electricity Energy Efficiency Measure Characterizations

Measures	End-Use Category	Annual savings per household (kWh)	Cost of Saved Energy ($/kWh)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (GWh)
Existing Building					2025		2025	2025	
Seal Ductwork	HVAC (load)	707	$ 0.09	yes	100%	15%	100%	4.2%	455
Insulate Ductwork, R-8	HVAC (load)	707	$ 0.03	yes	100%	15%	96%	4.1%	435
Infiltration reduction	HVAC (load)	884	$ 0.01	yes	100%	51%	92%	16.2%	1,733
Insulation, ceiling, R-11 to R-38	HVAC (load)	703	$ 0.01	yes	100%	28%	74%	5.6%	596
Insulation, ceiling, R-19 to R-38	HVAC (load)	314	$ 0.02	yes	100%	35%	74%	3.2%	339
Blow-in wall insulation	HVAC (load)	1,105	$ 0.03	yes	100%	20%	62%	5.3%	572
Cool Roof shingles	HVAC (load)	199	$ 0.06	yes	85%	77%	53%	2.7%	292
Estar Window, from single pane	HVAC (load)	4,454	$ 0.01	yes	57%	15%	48%	7.0%	748
Estar Window, from double pane	HVAC (load)	700	$ 0.04	yes	57%	65%	48%	4.9%	520
HVAC Load Reducing Measures								53%	5.690
Central HP (heating cycle); HSPF 9	HVAC (equipment)	1,640	$ 0.05	yes	94%	5%	47%	1%	151
GSHP w/ desuperheater (14 EER)	HVAC (equipment)	2,969	$ 0.07	yes	94%	0%	47%	0%	14
Central AC (cooling cycle) SEER 15	HVAC (equipment)	376	$ 0.02	yes	94%	50%	47%	3%	350
ENERGY STAR Dehumidifier	HVAC (equipment)	213	$ 0.02	yes	100%	8%	47%	0.3%	33
Room A/C (CEE Tier 2, 11.8 EER)	HVAC (equipment)	87	$ 0.04	yes	100%	23%	47%	0.4%	40
Ceiling Fan (including light kit)	HVAC (equipment)	245	$ 0.07	yes	100%	43%	47%	1.9%	206
HVAC Equipment Measures								7%	794
TOTAL HVAC								61%	6,484
High-efficiency showerheads (2gpm)	Water Heating	250	$ 0.01	yes	100%	60%	100%	18%	627
Faucet aerators (1.5 gpm)	Water Heating	48	$ 0.02	yes	100%	65%	100%	3.7%	130
Water heater pipe insulation	Water Heating	65	$ 0.05	yes	100%	88%	100%	6.8%	239
H-axis clothes washer (2.0 MEF) (water heating)	Water Heating	232	$ 0.06	yes	100%	64%	100%	17.7%	621
Dishwasher (Electric WH; 0.72 EF)	Water Heating	37	$ 0.07	yes	100%	85%	100%	3.7%	130

Measures	End-Use Category	Annual savings per household (kWh)	Cost of Saved Energy ($/kWh)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (GWh)
(water heating)									
Efficient electric water heater (0.93 EF)	Water Heating	117	$ 0.06	yes	100%	7%	54%	0.5%	17
Heat pump water heater (COP = 2.0)	Water Heating	2,185	$ 0.04	yes	100%	10%	54%	14%	504
Water Heating Savings								64%	2,269
Refrigerator (20%)	Refrigeration	114	$ 0.05	yes	89%	72%	100%	6.5%	307
Refrigerator (25%)	Refrigeration	29	$ 0.10	yes	89%	98%	100%	2.2%	104
Refrigeration Savings								9%	411
CFL, Advanced Incandescent Replacements	Lighting	1,003	$ (0.00)	yes	100%	90%	100%	55%	3,772
Lighting Savings								55%	3,772
H-axis clothes washer (2.0 MEF)	Appliances	26	$ 0.08	yes	100%	64%	100%	2%	69
Dishwasher (Electric WH; 0.68 EF)	Appliances	11	$ 0.08	yes	100%	85%	100%	1.3%	39
Appliances Savings								4%	108
Efficient Furnace Fan (Heating Season)	Furnace Fans	367	$ 0.05	yes	100%	46%	100%	28%	704
Efficient Furnace Fan (Cooling Season)	Furnace Fans	182	$ 0.05	yes	100%	46%	100%	13.9%	350
Furnace Fan Savings								42%	1,053
Energy Star Television Specification v. 3.0	Plug Loads	52	$ 0.10	yes	100%	74%	100%	1.4%	40
Set-Top Box Power Reduction	Plug Loads	120	$ 0.03	yes	100%	58%	100%	2.5%	72
1-watt standby power	Plug Loads	264	$ 0.02	yes	100%	66%	100%	6.2%	728
Total Plug Load Savings								10	840
In-home energy feedback monitor	All	577	$ 0.05	yes	100%	74%	69%	2.6%	1,248
New Construction Building Measures									
New home 15% better than code (Energy Star home)	New Construction	1,225	$ 0.04	yes	100%	17%	100%	2%	124
New home 30% better than code (Proposed Building Code)	New Construction	2,449	$ 0.04	yes	100%	35%	100%	7%	503
New home 50% better than code (Tax-credit-eligible)	New Construction	4,082	$ 0.04	yes	100%	47%	100%	17%	1,117
New Homes Subtotal									1,744

Table B-2. Residential Multifamily Electricity Energy Efficiency Measure Characterizations

Measures	End-Use Category	Annual savings per household (kWh)	Cost of Saved Energy ($/kWh)	Pass Cost-Effective Test?	% Turn-over	Adjust-ment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (GWh)
Existing Building					2025		2025	2025	
Exhaust fans, install timers	HVAC	175	$ 0.01	yes	100%	100%	100%	12%	194
Room A/C (CEE Tier 2, 11.8 EER)	HVAC	87	$ 0.04	yes	100%	24%	88%	1%	20
Total HVAC								13%	214
Replace water heating system (.95 EF)	Water Heating	47	$ 0.10	yes	68%	78%	100%	5%	28
Dishwasher (Electric WH; 0.72 EF) (water heating)	Water Heating	37	$ 0.07	yes	100%	85%	95%	6%	18
H-axis clothes washer (2.0 MEF) (water heating)	Water Heating	232	$ 0.06	yes	100%	64%	89%	27%	78
Water Heating Savings								38%	108
Refrigerator (20% Less Than 2001 Standard, EStar)	Refrigeration	114	$ 0.05	yes	89%	72%	100%	11%	82
Refrigeration Savings								11%	82
CFL installation (apts)	Lighting	591	$ 0.06	yes	100%	90%	100%	56%	591
Occupancy Sensors	Lighting	71	$ 0.08	yes	100%	90%	44%	3%	32
Lighting Savings								59%	623
Dishwasher (Electric WH; 0.72 EF)	Appliances	11	$ 0.08	yes	100%	85%	100%	2%	10
H-axis clothes washer (2.0 MEF)	Appliances	26	$ 0.08	yes	100%	64%	100%	4%	18
Appliances Savings								6%	29
Energy Star Televsion Specification,	Plug Loads	52	$ 0.09	yes	100%	74%	100%	2%	43

Measures	End-Use Category	Annual savings per household (kWh)	Cost of Saved Energy ($/kWh)	Pass Cost-Effective Test?	% Turn-over	Adjust-ment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (GWh)
Version 3.0									
Low power consumption on Set-Top Boxes	Plug Loads	120	$ 0.03	yes	100%	58%	100%	4%	77
1-watt standby power for consumer electronics	Plug Loads	264	$ 0.02	yes	100%	66%	100%	11%	194
Total Plug Load Savings								17%	313
Electricity Use Feedback	All	320	$ 0.07	yes	100%	11%	81%	5%	32

Natural Gas

Table B-3. Residential Single Family Natural Gas Energy Efficiency Measure Characterizations

Measures	End-Use Category	Annual savings per household (MMbtu)	Cost of Saved Energy ($/MMbtu)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (MMbtu)
Existing Building					2025		2025	2025	
Programmable thermostat	Space Heating (load)	4.6	$ 3.13	yes	100%	50%	100%	4%	6,103
Seal Ductwork	Space Heating (load)	9.0	$ 6.69	yes	85%	15%	96%	2%	2,980
Insulate Ductwork, R-8	Space Heating (load)	1.5	$ 12.77	yes	68%	15%	94%	0%	388
Infiltration reduction	Space Heating (load)	7.0	$ 1.38	yes	100%	51%	93%	6%	8,849
Insulation, ceiling, R-11 to R-38	Space Heating (load)	6.6	$ 2.42	yes	85%	28%	87%	2%	3,527
Insulation, ceiling, R-19 to R-38	Space Heating (load)	3.3	$ 4.83	yes	85%	35%	87%	2%	2,245
Space heating pipe insulation	Space Heating (load)	0.7	$ 3.87	yes	100%	50%	82%	1%	758
Blow-in wall insulation, R-13	Space Heating (load)	10.3	$ 3.01	yes	57%	20%	81%	2%	2,507
Estar Window, from single pane	Space Heating (load)	21.8	$ 1.34	yes	57%	15%	79%	3%	3,794
Estar Window, from double pane	Space Heating (load)	6.5	$ 4.49	yes	57%	65%	79%	4%	5,025

Measures	End-Use Category	Annual savings per household (MMbtu)	Cost of Saved Energy ($/MMbtu)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (MMbtu)
Space Heating Load Reducing Measures								**25%**	**36,176**
Energy Star Boiler, Condensing, AFUE >= 85	Space Heating (equipment)	10.6	$ 6.82	yes	85%	20%	75%	2%	3,540
Energy Star Furnace, Condensing, AFUE >= 90	Space Heating (equipment)	7.2	$ 3.80	yes	94%	46%	75%	4%	6,139
Energy Star Furnace, Condensing, AFUE >= 94	Space Heating (equipment)	2.0	$ 8.67	yes	94%	46%	75%	1%	1,683
Space Heating Equipment Measures								**8%**	**11,363**
TOTAL Space Heating								**33%**	**47,539**
High-efficiency natural gas water heater (0.65 EF)	Water Heating	2.5	$ 7.43	yes	100%	26%	100%	4%	940
Condensing Gas Storage water heater (0.86 EF)	Water Heating	8.5	$ 9.37	yes	100%	27%	100%	12%	3,264
Demand/Instantaneous, Tankless Water Heater (0.80 EF)	Water Heating	7.1	$ 8.44	yes	85%	23%	100%	7%	1,508
High-efficiency showerheads	Water Heating	1.0	$ 2.99	yes	100%	50%	100%	3%	922
Faucet aerators	Water Heating	1.0	$ 0.91	yes	100%	50%	100%	3%	922
Water heater pipe insulation	Water Heating	0.5	$ 4.99	yes	100%	88%	74%	2%	510
H-axis clothes washer (2.0 MEF) (water heating)	Water Heating	1.1	$ 13.61	yes	100%	64%	74%	3%	799
Dishwasher (Gas WH; 0.72 EF) (water heating)	Water Heating	0.3	$ 9.07	yes	100%	85%	74%	1%	276
Water Heating Savings								**34%**	**9,141**
Oven w/ electric ignition	Cooking	0.4	$ 9.34	yes	94%	100%	100%	**9%**	377
New Construction Building Measures									
New home 15% better than code (Energy Star home)	New Construction	10.8	$ 4.83	yes	100%	17%	100%	**2%**	248
New home 30% better than code (Proposed Building Code)	New Construction	21.7	$ 4.44	yes	100%	35%	100%	**9%**	1,008
New home 50% better than code (Tax-credit-eligible)	New Construction	36.1	$ 5.00	yes	100%	47%	100%	**20%**	2,240
New Homes Subtotal								**31%**	**3,497**

Table B-4. Residential Multifamily Natural Gas Energy Efficiency Measure Characterizations

Measures	End-Use Category	Annual savings per household (MMbtu)	Cost of Saved Energy ($/MMbtu)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (MMbtu)
Existing Building					2025		2025	2025	
Air Sealing	Space Heating (load)	2.08	$ 11.58	yes	85%	90%	100%	8%	1087
High Performance Windows, Double Pane, Low-E, low conductivity frame, Tier 1	Space Heating (load)	1.04	$ 10.03	yes	57%	60%	92%	2%	223
Improved Roof Insulation, R-11 to R-30	Space Heating (load)	0.62	$ 11.77	yes	57%	63%	91%	1%	138
Oxygen Trim	Space Heating (load)	1.04	$ 0.26	yes	100%	33%	90%	1%	208
Pipe Insulation	Space Heating (load)	0.42	$ 0.22	yes	100%	33%	88%	1%	82
Programmable Thermostat	Space Heating (load)	1.46	$ 9.93	yes	100%	100%	87%	6%	868
Steam Trap Maintenance	Space Heating (load)	0.62	$ 3.50	yes	100%	33%	80%	1%	112
Mainline Air Vents	Space Heating (load)	2.08	$ 2.59	yes	57%	25%	79%	1%	158
Thermostatic Steam Valves	Space Heating (load)	1.99	$ 9.63	yes	85%	20%	78%	1%	179
Space Heating Load Reducing Measures								**21%**	**3055**
Improved Heating System, High Efficiency Unit, Tier 1	Space Heating (equipment)	1.25	$ 0.74	yes	68%	40%	79%	1%	183
Front End Boiler	Space Heating (equipment)	10.39	$ 0.52	yes	57%	30%	79%	6.6%	940
Steam Boiler, 82% AFUE	Space Heating (equipment)	2.83	$ 9.00	yes	57%	20%	79%	1.2%	169
Space Heating Equipment Measures								**9%**	1292
TOTAL Space Heating								**31%**	**4347**

Measures	End-Use Category	Annual savings per household (MMbtu)	Cost of Saved Energy ($/MMbtu)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (MMbtu)
Condensing Gas Storage water heater (0.86 EF)	Water Heating	2.22	$ 0.92	yes	100%	63%	39%	7.6%	374
Commercial Clothes Washer (2.0 MEF)	Water Heating	2.58	$ 0.40	yes	100%	68%	100%	24%	1200
Dishwasher (Electric WH; 0.72 EF) (water heating)	Water Heating	1.00	$ 2.40	yes	100%	65%	100%	9%	444
Faucet Aerator, 1.5 gpm	Water Heating	0.43	$ 2.11	yes	100%	70%	100%	4.2%	206
Low-flow Showerheads	Water Heating	0.43	$ 6.92	yes	100%	70%	100%	4.2%	206
Pipe Insulation	Water Heating	0.72	$ 13.43	yes	100%	45%	100%	5%	221
Pump/Demand Controller	Water Heating	1.15	$ 3.62	yes	100%	48%	100%	8%	377
Graywater Heat Exchanger	Water Heating	2.87	$ 6.44	yes	85%	20%	100%	7%	333
Water Heating Savings								**69%**	**3361**
Oven w/ electric ignition	Cooking	0.29	$ 11.71	yes	94%	52%	100%	**10%**	**98**
New Construction Building Measures									
Integrated Design (30% > Codes) Tier 1	New Construction	8.39	$ 9.40	yes	34%	93%	100%	**9%**	**1813**

Fuel Oil

Table B-5. Single-Family Oil Measures

Measures	End-Use Category	Annual savings per household (gallons)	Cost of Saved Energy ($/gallon)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (Mgal)
Forced Air Space Heating									
Insulation	Load (Forced Air)	$169.13	$0.22	yes	23%	11%	100%	1%	10.5
Infiltration reduction	Load (Forced Air)	$60.41	$0.21	yes	70%	21%	98%	1%	12.2
Duct sealing	Load (Forced Air)	$75.51	$0.64	yes	47%	14%	96%	1%	9.9
Setback thermostat	Load (Forced Air)	$42.28	$0.28	yes	47%	14%	94%	0%	1.1
New windows	Load (Forced Air)	$64.03	$0.61	yes	23%	16%	94%	0%	3.7
Space Heating Load Reducing Measures								3%	37.5
Replace burner	Equipment (Forced-Air)	$90.61	$0.48	yes	47%	3%	94%	0%	0
Replace heating system		$100.68	$1.27	yes	39%	11%	94%	1%	20.9
Space Heating Equipment Measures								1%	20.9
Total Oil Forced Air								5%	58.3
Hot Water Space Heat									
Insulation	Load (Hot Water)	$169.13	$0.22	yes	23%	23%	100%	2%	22.4
Infiltration reduction	Load (Hot Water)	$60.41	$0.21	yes	70%	40%	96%	3%	23.2
Modulate water temp.	Load (Hot Water)	$90.61	$0.48	yes	47%	5%	92%	0%	4.4
Setback thermostat	Load (Hot Water)	$42.28	$0.28	yes	47%	27%	91%	1%	9.1
New windows	Load (Hot Water)	$64.03	$0.61	yes	23%	32%	90%	1%	14.7
Space Heating Load Reducing Measures								6%	73.8
Replace burner	Equipment (Hot Water)	$90.61	$0.48	yes	28%	23%	88%	0.0%	0
Replace heating system	Equipment (Hot Water)	$100.68	$1.27	yes	47%	45%	88%	0.2%	2.3
Space Heating Equipment Measures								0%	2.3
Total Oil Hot Water Space Heat								7%	76.1
Single Family Oil Steam Space Heat									

Insulation	Load (Steam Heat)	$169.13	$0.22	yes	23%	3%	87%	0%	2.2
Infiltration reduction	Load (Steam Heat)	$60.41	$0.21	yes	70%	4%	87%	0%	2.3
Improved steam vents	Load (Steam Heat)	$90.61	$0.48	yes	47%	3%	86%	0%	2.5
Setback thermostat	Load (Steam Heat)	$42.28	$0.28	yes	47%	3%	86%	0%	1.2
New windows	Load (Steam Heat)	$64.03	$0.61	yes	23%	4%	86%	0%	1.1
Space Heating Load Reducing Measures								1%	9.3
Replace burner	Equipment (Steam Heat)	$90.61	$0.48	yes	28%	1%	86%	0%	0
Replace heating system	Equipment (Steam Heat)	$103.13	$1.24	yes	35%	3%	86%	3%	33.9
Space Heating Equipment Measures								3%	33.9
Total Oil Steam Space Heat								3%	43.2
Single Family Oil Water Heating									
Pipe wrap	Water Heating	$22.03	$0.12	yes	47%	45%	100%	2%	10.0
Showerheads/faucets	Water Heating	$24.23	$0.12	yes	70%	64%	95%	5%	14.6
Low water clothes washer	Water Heating	$39.51	$0.38	yes	50%	72%	88%	6%	25.0
Combo SH/WH system	Water Heating	$76.24	$0.70	yes	28%	41%	76%	3%	15.9
Total Water Heating Savings								16%	65.5

Table B-6. Multi-Family Oil Measures

Measures	End-Use Category	Annual savings per household (gallons)	Cost of Saved Energy ($/gallon)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (Mgal)
Hot Water Space Heat									
Infiltration reduction	Load (Hot Water Space Heating)	$18.19	$1.78	yes	70%	54%	100%	4%	2.6
Attic insulation		$5.46	$1.12	yes	23%	39%	95%	0%	0.3
Modulate water temp.		$20.01	$0.08	yes	47%	18%	94%	1%	0.9
New windows		$19.29	$1.35	yes	23%	36%	92%	1%	1.0
Space Heating Load Reducing Measures								6%	4.8
Replace burner	Equipment (Hot Water)	$27.29	$0.07	yes	47%	6%	90%	0%	0.4
Front-end boiler		$18.19	$0.60	yes	23%	12%	90%	0%	0.3
Replace heating system		$30.32	$0.40	yes	23%	34%	90%	1%	1.4
Space Heating Equipment Measures								2%	2.1
Total Oil Hot Water Space Heat								8%	6.8
Multi Family Oil Steam Space Heat									
Infiltration reduction	Load (Steam Heat)	$18.19	$1.78	yes	70%	41%	88%	3%	1.7
Attic insulation		$5.46	$1.12	yes	23%	32%	87%	0%	0.2
Mainline air vents		$18.19	$0.25	yes	23%	34%	87%	0%	0.1
Thermostatic vents		$10.92	$1.76	yes	35%	18%	86%	1%	0.6
New windows		$19.29	$1.35	yes	23%	27%	84%	1%	0.8
Space Heating Load Reducing Measures								4%	3.5
Replace burner	Equipment (Steam Heat)	$27.29	$0.07	yes	47%	5%	81%	0%	0.3
Replace heating system		$31.06	$0.89	yes	23%	27%	81%	1%	1.0
Space Heating Equipment Measures								1%	1.3
Total Oil Steam Space Heat								5%	4.7
Multi Family Water									

Heating									
Pipe wrap	Water Heating	$6.63	$1.45	yes	47%	50%	100%	2%	0.9
Showerheads/faucets	Water Heating	$7.30	$0.62	yes	70%	70%	95%	5%	1.3
Low water clothes washer	Water Heating	$11.90	$3.40	yes	50%	60%	87%	5%	1.7
Combo SH/WH system	Water Heating	$22.96	$3.48	yes	28%	55%	77%	5%	1.7
Pump controller	Water Heating	$10.61	$0.35	yes	47%	60%	64%	4%	1.1
Total Water Heating Savings								21%	6.6

Propane

Table B-7. Single-Family Propane Measures

Measures	End-Use Category	Annual savings per household (gallons)	Cost of Saved Energy ($/gallon)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (Mgal)
Residential Propane Space Heating									
Insulation	Load	$166.32	$0.86	yes	100%	60%	100%	15%	10
Infiltration reduction	Load	$52.75	$0.86	yes	85%	75%	85%	4%	3
Duct sealing	Load	$60.99	$0.79	yes	68%	15%	80%	1%	1
Replace heating system	Equipment	$127.06	$0.77	yes	100%	46%	79%	7%	5
Setback thermostat	Load	$28.46	$0.42	yes	85%	50%	70%	1%	1
New windows	Load	$41.59	$0.94	yes	85%	60%	70%	2%	1
Total Space Heating								30%	20
Residential Propane Water Heating									
Pipe wrap	Water Heating	$18.30	$0.53	yes	100%	88%	100%	9%	2
Showerheads/faucets		$19.12	$0.24	yes	100%	70%	91%	7%	1
Low water clothes washer		$28.79	$1.40	yes	85%	79%	93%	10%	2
New water heater		$6.66	$1.20	yes	100%	95%	89%	3%	1
Total Water Heating								28%	5
Residential Propane Appliances									
Oven w/ electric ignition	Appliance	$16.01	$0.21	yes	94%	100%	100%	14%	1
Efficient Clothes Dryer	Appliance	$23.87	$0.22	yes	100%	80%	86%	15%	2
Total Appliances								30%	3

Residential Sector Measure Descriptions – Electricity and Natural Gas

Single Family

In-home energy feedback monitor (Electricity Only)

Measure Description: A device installed inside the home that communicates with the electric meter and displays real-time electricity use information to occupants.

Basecase: Average metered home with no feedback mechanism other than monthly utility bills

Data Explanation: Total households applicable (75%) from Economy.com (2008) for single-family households. Baseline electricity consumption is for an average household excluding multifamily buildings above four units from RECS (EIA 2003). Cost ($250) includes cost of product ($150) plus one hour of installation ($100) from Parker 2006. Percent savings (5%) from ACEEE 2007 and Stein 2004. Useful life (11 years) assumed to be similar to programmable thermostat, from ACEEE 2007. Penetration in residential sector technically achievable in all metered residential units.

Programmable Thermostat (Natural Gas Only)

Measure Description: Installation of a programmable thermostat to regulate indoor temperature, setback by five degrees Fahrenheit.

Basecase: Home without a programmable thermostat or temperature setback.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Savings (7%), measure life (15 yrs) and incremental cost ($150) from ACEEE 1994, adjusted for inflation. There are no documented savings for electricity from programmable thermostats, so for our study we have limited programmable thermostats to a natural gas savings measure.

Duct Sealing

Measure Description: Professional duct-sealing service suitable for retrofits and new construction, involving testing and either hand-applied or aerosol-based mastic (Jump 2006).

Basecase: Single-family home with a forced-air furnace and air conditioner.

Data Explanation: Baseline energy use from RECS (EIA 2003) depending on primary fuel use. Electricity savings (10%) in each season (cooling and heating) is derived from 80% reduction in duct leakage (Jump 1996), which comprises half of the 20% of total HVAC energy use that can be associated with duct-related energy losses (the other half being by conduction, [Hammurlund, 1992; Proctor, 1993]). Natural gas savings (9 MMBtu) from NYSERDA 2006. A cost of $750 is mature-market cost of Aeroseal, from Bourne, et al, 1999. Measure life is 20 years (SWEEP 2002).

Duct Insulation

Measure Description: R8 insulation applied to exposed ductwork in unconditioned spaces.

Basecase: Single-family home with a forced-air furnace and air conditioner with uninsulated ductwork passing through un-conditioned space (attic, un-finished basement, garage)

Data Explanation: Baseline energy use from RECS 2001 (EIA 2003) depending on primary fuel use. Electricity savings (10%) from SWEEP, based on 10% heating/cooing energy use in forced-air system associated with conductive duct losses. Natural Gas savings (1.5 MMBtu) and floor area (1800 sq.ft.) from average of three home types (colonial, ranch, wood-frame) adding together savings from upgrading from R-0 to R-3 and R-3 to R-6 (ACEEE 1994). Cost ($0.15/sq ft) from DEER Database (CEC 2005). Floor area (1800 sq. ft) based off average floor area of colonial and ranch single family detached from ACEEE 1994. Useful life is 25 years (SWEEP 2002).

Blower-Door Aided Infiltration Reduction

Measure Description: Application of foam and/or caulk around leakage areas applied and tested by a professional using a blower-door.

Basecase: Household with higher-than average heating and cooling energy use.

Data Explanation: Baseline energy use from RECS (EIA 2003) depending on primary fuel use, plus a 25% adder representing high-use homes. Electricity savings of 10% from MT Screening Reports. Natural gas savings (7 MMBtu) from NYSERDA 2006. Cost ($100) from MT 2004. Useful life of 15 years from SWEEP 2002. Savings applied to percentage of homes that report drafts (51%), from RECS 2005 (EIA 2008).

Attic Insulation

Measure Description: Add insulation in attic floor to R-38.

Basecase: R-11assumed for houses reported to be "well insulated."

Data Explanation: Savings (703 kWh, 8% for both electricity and natural gas) average of colonial and ranch savings for R11-R30 attic insulation from NYSERDA 1994, increased by multiplier (1.09) to incorporate savings from upgrading to R38. Total households applicable (28%) average from RECS 2005 for house that are "well insulated" and houses that are "not well insulated" (EIA 2008). Baseline energy use from RECS 2001 (EIA 2003) depending on primary fuel use, plus a 25% adder representing high-use homes. Incremental cost of $0.32/sq.ft. from DEER database (CEC 2005). Assumes 1000 s.f. of insulation needed. Useful measure life of 20 years from NYSERDA 2003.

Attic Insulation

Measure Description: Add insulation in attic floor to R-38.

Basecase: R-19 assumed for houses reported to be "well insulated."

Data Explanation: Savings (314 kWh, 4% for both electricity and natural gas) average of colonial and ranch savings for R19-R30 attic insulation from NYSERDA 1994, increased by multiplier (1.34) to incorporate savings from upgrading to R38. Total households applicable (35%) from RECS 2005 for house that are "well insulated" (EIA 2008). Baseline energy use from RECS 2001 (EIA 2003) depending on primary fuel use, plus a 25% adder representing high-use homes. Incremental cost of $0.32/sq.ft. from DEER database (CEC 2005). Assumes 1000 s.f. of insulation needed. Useful measure life of 20 years from NYSERDA 2003.

Space Heating Pipe Insulation (Natural Gas Only)

Measure Description: Add 10 linear feet of insulation

Base Case: No pipe insulation

Data Explanation: Savings (0.7 MMBtu) equals the average of three home types (colonial, ranch, wood-frame) for pipe insulation from NYSERDA 1994. Cost ($28) from DEER Database based off $0.37 per linear foot equipment cost and $2.44 per linear foot installation cost (CEC 2005). Measure life (15 yrs) from ACEEE 1994.

Blow-in Cellulose Wall Insulation

Measure Description: Add blow-in cellulose insulation to un-insulated wall cavities, R-0 to R-13

Basecase: Average-sized single-family home with wood-frame construction built before 1970.

Data Explanation: Total households applicable (20%) from RECS 2005 for houses that are "not well insulated" (EIA 2008). Baseline energy use from RECS, 2001 (EIA 2003), depending on primary fuel use, plus a 25% adder representing high-use homes. Electricity and natural gas savings of 13% and 1700 sq.ft. of uninsulated wall space are based on average of three house types from ACEEE 1994. Cost ($1.12/sq.ft, unit and installation cost) from DEER database (CEC 2005). Useful measure life of 30 years from NYSERDA 2003.

Cool Roof Shingles (Electricity Only)

Measure Description: Roof shingles that meet ENERGY STAR residential requirements for reflectivity and thermal emittance due to light color or other material properties.

Basecase: Standard high-pitched residential roof with dark asphalt shingles

Data Explanation: Baseline electricity reflects cooling load only, from RECS 2001 (EIA 2003). Savings of 20% of cooling load and cost ($.10/s.f.) are from ACEEE Emerging Technologies analysis (Sachs et al 2004). Roof area (1400 sq. ft) based off assumption of 1000 sq. ft for ceiling/attic area, multiplied by 1.4 (roof area generally 1.4 times greater than the area of the ceiling/attic). Percent of homes applicable (86%) are the percent of households with asphalt shingles, from Dejarlais, 2006 presentation (CEE Cool Roofs workshop). Market share (10%) and measure life (20 years) are from Sanchez, et al, 2007.

ENERGY STAR Windows

Measure Description: Window replacements that meet regional ENERGY STAR requirements for U value and solar heat gain coefficient (SHGC).

Basecase: Replacement of 20 *single-pane* windows measuring approximately 15 s.f. each.

Data Explanation: Baseline energy use from RECS 2001 for all-electric home (EIA 2003). Electricity savings (63%) from ratio of U-values associated with upgrading from single pane (U-value = 1.10) to Energy Star (U-value = .40), from Leckie et al., 1981. Natural gas savings (33%) from ratio of savings (21.8 MMBtu/yr, EPA 2005) to baseline consumption (EIA 2003). Incremental cost ($450) assumes 300 sq. ft. of windows at $1.50 per sq. ft. (NEEP 2006). Measure life (30) from SWEEP 2002. Percent applicable (31%) from RECS 2005 (EIA 2008).

ENERGY STAR Windows

Measure Description: Window replacements that meet regional ENERGY STAR requirements for U value and solar heat gain coefficient (SHGC).

Basecase: Replacement of 20 *double-pane* windows measuring approximately 15 s.f. each.

Data Explanation: Baseline energy use from RECS 2001 for all-electric home (EIA 2003). Savings (18% for electricity and natural gas) from ratio of U-values associated with upgrading from double pane (U-value = .49) to Energy Star (U-value = .40), from Lekcie et al., 1981. Incremental cost ($450) assumes 300 sq. ft. of windows at $1.50 per sq. ft. (NEEP 2006). Measure life (30) from SWEEP 2002. Percent applicable (65%) from RECS 2005 (EIA 2008).

Energy Star Efficient Boiler (Natural Gas Only)

Measure Description: AFUE 85%

Basecase: AFUE 75%

Data Explanation: Baseline consumption (90 MMBtu) and incremental cost ($900) from Energy Star Calculator (EPA 2008). Energy Star calculator input assumes ratio of HDD from Harrisburg, PA. Savings (12%) from ratio of EF increase (.1/.85). Measure life (20 yrs) from Sanchez et al. 2007. Market share (39%) from Sanchez et al. 2008.

High-efficiency Central Air Conditioner (Cooling Only, Electricity Only)

Measure Description: SEER 15, 3 ton unit

Basecase: Current federal standard: SEER 13, 3 ton unit

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Percent savings (27%) and incremental cost ($93) from Energy Star calculator for Central Air Conditioners using Philadelphia, PA, as a proxy. Measure life (18 yrs) from Sanchez, et al, 2007. Market share (11%, assumed to be half of market share for Energy Star qualified unit with SEER = 14) from Sanchez et al., 2008. Percent applicable (56%) equivalent to households with central AC, with and w/o heat pump (EIA 2008).

High-efficiency Heat Pump (Heating Only, Electricity Only)

Measure Description: HSPF 9

Basecase: Current federal standard: HSPF 7.7

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Percent savings (27%) and incremental cost ($1000) from Energy Star calculator for Air-Source Heat Pumps using Philadelphia, PA, as a proxy. Measure life (18 yrs) from Sanchez, et al, 2007. Market share (9%, assumed to be half of market share for Energy Star qualified unit with HSPF = 8.2) from Sanchez et al, 2008.

Efficient Furnace Fan (Heating Season - Electricity)

Measure Description: High efficiency, ECM fan

Basecase: PSC fan

Data Explanation: Baseline electricity consumption from Lutz (2004), accounting for parasitics and adjusted by state heating hours (2250) from ARI 2003. Percent applicable (51%) equivalent to sum of households with forced air systems (EIA 2008). Electricity savings (367 kWh, 68%) from Pigg 2003 and state heating hours assumed (2250), from ARI 2003. Incremental costs ($200) from Sachs & Smith 2004, apportioned by ratio of seasonal savings ($134).

Efficient Furnace Fan (Cooling Season - Electricity)

Measure Description: High efficiency, ECM fan

Basecase: PSC fan

Data Explanation: Baseline electricity consumption from Lutz (2004), accounting for parasitics and adjusted by state cooling hours (800), from ARI 2003. Percent applicable (51%) equivalent to sum of households with forced air systems (EIA 2008). Electricity savings (182 kWh, 36%) from Pigg 2003 and state hours assumed (800) from ARI 2003. Incremental costs ($200) from Sachs & Smith 2004, apportioned by ratio of seasonal savings ($66).

Energy Star Efficient Furnace (Natural Gas)

Measure Description: AFUE 90%

Basecase: AFUE 78%

Data Explanation: Baseline consumption and incremental cost ($320) from Energy Star Calculator (EPA 2008c). Energy Star calculator input assumes ratio of HDD from Harrisburg, PA. Savings (13%) from ratio of EF increase (.12/.90). Measure life (18 yrs) from Sanchez et al. 2007. Market share (32%) from Sanchez et al. 2008.

Energy Star Efficient Furnace (Natural Gas)

Measure Description: AFUE 94%

Basecase: AFUE 90%

Data Explanation: Baseline consumption from Energy Star Calculator (EPA 2008c). Energy Star calculator input assumes ratio of HDD from Harrisburg, PA. Savings (4%) from ratio of EF increase (.4/.94). Measure life (18 yrs) from Sanchez et al. 2007. Market share (32%) from Sanchez et al. 2008.

Ground-Source Heat Pump (Electricity Only)

Measure Description: Closed ground-source heat pump with EER 14.

Basecase: Conventional air-source heat pump of SEER 13, HSPF 7.7

Data Explanation: Baseline energy use (for homes with electricity as primary fuel multiplied by 2 for high-use homes) from RECS 2001(EIA 2003).Savings (21%) and cost ($2400) from ACEEE Emerging Technologies analysis (Sachs 2007). Analysis assumes technical feasibility in 10% of houses with forced-air electric heat (0.3%). Measure life (18 years) from Sachs 2007.

Efficient Electric Storage Water Heater (Electricity Only)

Measure Description: 50-gallon electric storage water heater, 0.93 EF. We adjust to account for the fact that more-efficient water heaters are typically cost-effective only for households with more than 3 members.

Basecase: Current federal standard for typical, 50-gallon electric storage water heater, 0.90 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), increased by ratio (1.5) to account for greater consumption from households with 3 or more members (EIA 2008). Percent applicable (10%) equivalent to houses with natural gas water heaters multiplied by the number of households with 3 or more members (EIA 2008). Savings (3%) derived from EF increase. Incremental cost ($70) from Amann, et al., 2007. Measure life (14 years) from NYSERDA 2003. Market share (36%) estimated based on percent of products on the market meeting EF 0.93 in the GAMA product database (GAMA 2007).

High-Efficiency Natural Gas Storage Water Heater (Natural Gas Only)

Measure Description: 50-gallon natural gas storage water heater, 0.65 EF. We adjust several variables to account for the fact that more-efficient water heaters are typically cost-effective only for households with more than 3 members.

Basecase: Current federal standard for typical, 50-gallon natural gas storage water heater, 0.59 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), increased by ratio (1.5) to account for greater consumption from households with 3 or more members (EIA 2008). Savings (9%) from ratio of EF increase (.6/.65). Incremental cost ($175) from Amann, et al., 2007. Measure life (13 yrs) from NYSERDA 2006. Percent applicable (27%) equivalent to houses with natural gas water heaters multiplied by the number of households with 3 or more members (EIA 2008).

Condensing Gas Storage Water Heater (Natural Gas Only)

Measure Description: 50-gallon natural gas storage water heater, 0.86 EF. We adjust several variables to account for the fact that more-efficient water heaters are typically cost-effective only for households with more than 3 members.

Basecase: Current federal standard for typical, 50-gallon natural gas storage water heater, 0.59 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), increased by ratio (1.5) to account for greater consumption from households with 3 or more members (EIA 2008). Savings (31%) from ratio of EF increase (.27/.86). Incremental cost ($750) and measure life (13 yrs) from Amann, et al., 2007. Percent applicable (27%) equivalent to houses with natural gas water heaters multiplied by the number of households with 3 or more members (EIA 2008).

Demand/Instantaneous Tankless Water Heater (Natural Gas Only)

Measure Description: 0.80 EF. We adjust several variables to account for the fact that more-efficient water heaters are typically cost-effective only for households with more than 3 members.

Basecase: Current federal standard for typical, 50-gallon natural gas storage water heater, 0.59 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), increased by ratio (1.5) to account for greater consumption from households with 3 or more members (EIA 2008). Savings (26%) from ratio of EF increase (.21/.80). Incremental cost ($750) and measure life (20 yrs) from Amann, et al., 2007. Market share (15%) equal to number of products with EF = .80, from GAMA 2008. Percent applicable (27%) equivalent to houses with natural gas water heaters multiplied by the number of households with 3 or more members (EIA 2008).

Heat Pump Water Heater (Electricity Only)

Measure Description: Either add-on or integrated heat-pump that uses the evaporation-compression cycle to extract heat from surrounding air to heat water in a conventional storage tank. COP 2.0 or above. We adjust to account for the fact that more-efficient water heaters are typically cost-effective only for households with more than 3 members.

Basecase: Current federal standard for typical, 50-gallon electric storage water heater, 0.90 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), increased by ratio (1.5) to account for greater consumption from households with 3 or more members (EIA 2008). Percent applicable (10%) equivalent to houses with natural gas water heaters multiplied by the number of households with 3 or more members (EIA 2008). Savings (60%) and measure life (14.5 years) are from Sachs, et al 2004. Incremental cost ($910) based off electric heat pump with COP=2.2, from Amann, et al., 2007.

High-efficiency showerheads

Measure Description: 2.0 gallons per minute (gpm) showerhead

Basecase: Assumes electric and gas water heater meeting current federal standard (see Electric Storage Water heater above). Showerhead meets federal requirements of 2.5 gpm

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Electricity savings (10%) from Brown, et al, 1987. Natural gas savings (5.5%) equals half of the average of three home types (colonial, ranch, wood-frame) of savings for both showerheads and faucet aerators (11%), from ACEEE 1994 (p.2-50). Cost estimate ($23) for a low-cost, basic model from the DEER database (CEC 2005). Measure life (10 yrs) from ACEEE 1994. Percent applicable (100%) is percentage of households with electric water heating (EIA 2008).

Faucet Aerators

Measure Description: 1.5 gallons per minute (gpm) faucet aerator

Basecase: Assumes electric and gas water heater meeting current federal standard (see Electric Storage Water heater above). Baseline aerator meets federal requirements of 2.5 gpm

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Electricity savings (2%) from Frontier Associates (2006). Natural gas savings (5.5%) equals half of the average of three home types (colonial, ranch, wood-frame) of savings for both showerheads and faucet aerators (11%), from ACEEE 1994 (p.2-50). Cost estimate ($7) for a low-cost, basic model from the DEER database (CEC 2005). Measure life (10 yrs) from ACEEE 1994. Percent applicable (100%) is percentage of households with electric water heating (EIA 2008).

Water Heater Pipe Insulation

Measure Description: Insulating 10 feet of exposed pipe in unconditioned space, ¾" thick.

Basecase: Assumes electric and gas water heater meeting current federal standard (see Electric Storage Water heater above).

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003). Electricity savings (3%) from CL&P 2007. Natural gas savings (3%) from ACEEE 1994 (p. 2-42). Costs ($28) from DEER Database based off $0.37 per linear foot equipment cost and $2.44 per linear foot installation cost (CEC 2005). Measure life (13 yrs) from Efficiency Vermont, 2005. Percent applicable (100%) is percentage of households with electric water heating (EIA 2008).

Efficient Dehumidifier (Electricity Only)

Measure Description: Replacement dehumidifier that is ENERGY STAR certified based on the 2008 Energy Star specification.

Basecase: Dehumidifier that meets current (2005) federal energy standards.

Data Explanation: Baseline ($150) and incremental costs ($30) and electricity consumption from Energy Star savings calculator. Percent applicable (20%) equivalent to percent of households with a dehumidifier (EIA 2008). Percent savings (19%) and measure life (12 years) from Sanchez et al, 2007. Market share (60%) from Sanchez et al, 2008.

Efficient Room Air Conditioner (Electricity Only)

Measure Description: Energy Star Room A/C (10000 Btu unit at 10.8 EER).

Basecase: Room A/C that meets 2000 federal energy standards (10000 Btu at 9.8 EER)

Data Explanation: Baseline consumption and incremental cost ($30) from Energy Star savings calculator. Savings (17%) calculated by increase in EER. Percent homes applicable (48%) based on number of homes with Room A/C unit from RECS 2005 (EIA 2008). Measure life (13 years) from Sanchez, et al, 2007. Market share (51%) from Energy Star 2006 appliance sales data specific to Pennsylvania (EPA 2007).

Refrigerator Tier I (Electricity Only)

Measure Description: Replacement refrigerator that meets 2008 ENERGY STAR requirements (20% better than federal standard)

Basecase: Refrigerator that meets current 2001 federal energy standards.

Data Explanation: Baseline consumption, incremental cost ($64) and measure life (19 years) from ACEEE analysis for PG&E/CA Title 24 (PG&E, 2007). Market share (28%) from Energy Star 2006 appliance sales data specific to Pennsylvania (EPA 2007).

Refrigerator Tier II (Electricity Only)

Measure Description: Replacement refrigerator that exceeds federal energy standard by 25% (CEE Tier 2)

Basecase: Refrigerator that meets current 2001 federal energy standards.

Data Explanation: Baseline consumption, incremental cost ($34) and measure life (19 years) from ACEEE analysis for PG&E/CA Title 24 (PG&E, 2007). Market share (2%) equivalent to percent of Energy Star products that exceed federal standard by 25%.

Horizontal-Axis Clothes Washer (water heating)

Measure Description: Front-loading (H-axis) clothes washer meeting ENERGY STAR requirements (2.0 MEF)

Basecase: Federal standard for clothes washers: 1.26 MEF

Data Explanation: Baseline consumption and savings (31% for electricity, 37% for natural gas) from EPA 2008a, isolating water heating energy savings only. Incremental cost ($147) apportioned based on percentage of electricity consumption dedicated to water heating less savings from decreased water usage ($33), from EPA 2008. Percent applicable (100%) based on appliance saturation data from RECS 2005 (EIA 2008). 2006 market share (36%) from EPA 2007. Measure life (14 years) is from Sanchez, et al, 2007.

Horizontal-Axis Clothes Washer (appliances, electricity only)

Measure Description: Front-loading (H-axis) clothes washer meeting ENERGY STAR requirements (2.0 MEF)

Basecase: Federal standard for clothes washers: 1.26 MEF

Data Explanation: Baseline consumption and savings (31%) from EPA 2008a, isolating appliance energy savings only. Incremental cost ($20) apportioned based on percentage of electricity consumption not dedicated to water heating. Percent applicable (100%) based on appliance saturation data from RECS 2005 (EIA 2008). 2006 market share (36%) from EPA 2007. Measure life (14 years) is from Sanchez, et al, 2007.

Efficient Dishwasher (appliances, electricity only)

Measure Description: Dishwasher meeting 2011 Energy Star requirement of 0.72 EF

Basecase: Dishwasher meeting 2010 federal energy standard of 0.62 EF

Data Explanation: Baseline consumption (200 kWh/yr) assumes 215 cycles/yr at .93 kWh per cycle, apportioned for appliance electricity use, from DOE 2007. Incremental cost ($8) and electricity savings from DOE 2007 Technical Support Document, isolating appliance energy savings only. Incremental cost apportioned based off ratio of electricity savings between the appliance and electricity used for water heating. Measure life (13 years) is from Sanchez, et al, 2007. Market share (15%) from April 2007 LBL analysis on the AHAM-efficiency advocate agreement.

Efficient Dishwasher (water heating)

Measure Description: Dishwasher meeting 2011 Energy Star requirement of 0.72 EF

Basecase: Dishwasher meeting 2010 federal energy standard of 0.62 EF

Data Explanation: Baseline consumption (146 kWh) assumes 215 cycles/yr at .68 kWh per cycle, apportion for water heating use, from DOE 2007. Incremental cost ($22) and energy savings from DOE 2007 Technical Support Document, isolating water heating energy savings only. Incremental cost apportioned based off ratio of electricity savings between the appliance and electricity used for water heating. Measure life (13 years) is from Sanchez, et al, 2007. Market share (15%) from April 2007 LBL analysis on the AHAM-efficiency advocate agreement.

Oven w/ electronic ignition (Natural Gas Only)

Measure Description: Installed electric ignition, improved insulation and improved door seals give EF = 0.062.

Basecase: Conventional oven with an EF = 0.059

Data Explanation: Baseline consumption and incremental cost ($40) from DOE 2006. Savings (20%) from Amann, et al. 2007 (p.160) Measure lifetime (18 yrs) from Appliance 2007.

Ceiling Fan (Electricity Only)

Measure Description: ENERGY STAR certified ceiling fan

Basecase: Standard ceiling fan as defined by ENERGY STAR

Data Explanation: Baseline consumption (573 kWh), new measure consumption (245 kWh), and incremental cost ($182) from ENERGY STAR calculator (assuming Mid Atlantic Region). 2.12 units per household assumed from RECS, 2005. Percent applicable (65%) equivalent to number of households with a ceiling fan. Measure life (10 years) from Sanchez, et al, 2007. Market share (34%) from Sanchez et al, 2008.

Compact Fluorescent Lighting (Electricity Only)

Measure Description: Savings from the 17-watt equivalent to baseline lamp (75%) applied to 80% of baseline incandescent lamp hours.

Basecase: Baseline house requires 25,659 incandescent lamp-hours per year; average incandescent wattage is 63 watts based on 2001 federal government lighting inventory survey (DOE 2002).

Data Explanation: Measure of 80% replacement by lamp-hours is ACEEE assumption based on a conservative estimate of feasible applications. Applies to all households. Market share (10%) from ACEEE estimate based on EPA's estimate of Energy Star lamp sales in 2007 and ACEEE's estimate of total lamp sales.

Active Mode Efficiency for Televisions (Electricity Only)

Measure Description: Energy Star Television Specification, Version 3.0

Basecase: Average of all TVs from ENERGY STAR data set (CEE 2008).

Data Explanation: Baseline consumption (371 kWh), new measure consumption (319 kWh), measure life (6 yrs), and savings from CEE 2008.

Low Power Set-Top Boxes (Electricity Only)

Measure Description: Require digital set-top boxes to have a maximum sleep state power level of 10 watts and to automatically enter sleep mode after 4 hours without user input.

Basecase: Typical house with 1.9 set top boxes, operating at an average of up to 350 kWh/yr (Rainer, 2008).

Data Explanation: All data except cost from Rainer 2008. No reliable incremental cost data is available. In the case of set-top boxes, efficiency measures are largely software-related, likely resulting in very low cost per kWh saved per household. Our cost estimate is set to result in a levelized cost similar to that for TVs.

One-Watt Standby for All Household Electronics (Electricity Only)

Measure Description: All new electronics devices required to have maximum “off” mode power level of 1 watt.

Basecase: Typical house with 15 devices that consume 50 watts standby power.

Data Explanation: Baseline consumption, savings, incremental costs and measure life available from ACEEE 2004 emerging technologies analysis (Sachs et al. 2004). Penetration of new measure assumed by averaging market shares of all ENERGY STAR home electronics equipment.

ENERGY STAR New Home

Measure Description: New home that uses 15% less energy than code

Basecase: Code-compliant home (proposed 2008 IECC residential code revision)

Data Explanation: Baseline equals delivered HVAC and water heating energy use per household (across all households) from AEO (2007). Incremental costs ($805) from personal communication with Shadid (2007). Market share (1.5%) from EPA 2007a. Percent applicable for new homes assume that 30% and 50% new buildings are phased-in one to two years prior to enactment of codes (30% in 2012 and 50% in 2020).

Advanced Building Code New Home

Measure Description: New home that uses 30% less energy than code

Basecase: Code-compliant home (proposed 2008 IECC residential code revision)

Data Explanation: Baseline equals delivered HVAC and water heating energy use per household (across all households) from AEO (2007). Incremental costs ($1480) and market share (0%) from personal communication wtih Shadid (2007). Percent applicable for new homes assume that 30% and 50% new buildings are phased-in one to two years prior to enactment of codes (30% in 2012 and 50% in 2020).

Tax-Credit-Eligible New Home

Measure Description: New home that uses 50% less energy than code.

Basecase: Code-compliant home (proposed 2008 IECC residential code revision)

Data Explanation: Baseline equals delivered HVAC and water heating energy use per household (across all households) from AEO (2007). Incremental costs ($2775) and market share (0%) from personal communication wtih Shadid (2007). Percent applicable for new homes assume that 30% and 50% new buildings are phased-in one to two years prior to enactment of codes (30% in 2012 and 50% in 2020).

Residential Sector – Multi Family

In-home energy feedback monitor (Electricity Only)

Measure Description: A device installed inside the multifamily building that communicates with the electric meter and displays real-time electricity use information to occupants.

Basecase: Average metered home with no feedback mechanism other than monthly utility bills

Data Explanation: Total households applicable (11%) from RECS 2005 for multifamily units in buildings with 2-4 units as feedback monitors are only applicable in these types of buildings. Baseline electricity consumption from RECS 2001 (EIA 2003). Incremental cost ($374) from NYSERDA 2007, spread over two units. Percent savings (5%) from ACEEE 2007 and Stein 2004. Useful life (11 years) assumed to be similar to programmable thermostat, from ACEEE 2007.

Air Sealing (Natural Gas Only)

Measure Description: Application of foam and/or caulk around leakage areas.

Basecase: Typical construction with substantial air infiltration.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings of 10% from MT Screening Reports. Measure life (20 yrs) from NYSERDA 2006. Incremental cost ($300, adjusted for inflation) from ACEEE 1994.

Efficient Low-E Windows (Natural Gas Only)

Measure Description: High performance windows, double pane, low-e, low-conductivity frame, Tier 1

Basecase: Standard double glazed windows without low-e coating.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Incremental cost ($154.20 per MMBtu of savings) from NYSERDA 2006. Percent savings (5%, average of upstate and downstate energy fractions) and measure life (30 yrs) from NYSERDA 2006. Market share (40%) from PA oil analysis.

Improved Roof Insulation (Natural Gas Only)

Measure Description: Upgrade to R-30 insulation.

Basecase: R-11 insulation

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003), adjusted for percent of PA multifamily building stock (Economy.com 2008). Incremental cost ($113 from ACEEE 1994, spreading cost among apartments on six floors and adjusted for inflation. Measure life (30 yrs) from NYSERDA 2006. Savings (3%) from MA 2004 code analysis. Market share (30%) from PA oil analysis.

CFL Installation (Apts, Electricity Only)

Measure Description: Savings from the 17-watt equivalent to baseline lamp (75%) applied to 80% of baseline incandescent lamp hours.

Basecase: Incandescent lighting in apartment; average incandescent wattage is 63 watts based on 2001 federal government lighting inventory survey (DOE 2002).

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (591 kWh, 62%) and incremental cost ($239) from NYSERDA 2007. Market share (10%) from ACEEE estimate based on EPA's estimate of Energy Star lamp sales in 2007 and ACEEE's estimate of total lamp sales.

Oxygen Trim (Natural Gas Only)

Measure Description: Reduction of excess air in flue gas mixture for increased efficiency.

Basecase: No oxygen trim.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Baseline consumption from RECS 2001 (EIA 2003), adjusted for percent of PA multifamily building stock (Economy.com 2008). Percent savings (5%, average of upstate and downstate), incremental cost ($1.97 per MMBtu of savings), and measure life (10 yrs) from NYSERDA 2006. Percent applicable (33%) equal to households heating with natural gas that use boilers.

Occupancy Sensors (Electricity Only)

Measure Description: Installation of occupancy sensors.

Basecase: No occupancy sensors.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Energy savings assumes 7.5% reduction in open spaces (ACEEE estimate). Incremental cost ($48) and measure life (11 yrs) from NYSERDA 2003.

Pipe Insulation (Space Heating, Natural Gas Only)

Measure Description: Insulation of piping for boiler water.

Basecase: Uninsulated pipes.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Percent savings (2%, average of upstate and downstate), incremental cost ($2.29 per MMBtu of savings), and measure life (15 yrs) from NYSERDA 2006.

Programmable Thermostat (Natural Gas Only)

Measure Description: Installation of programmable thermostat

Basecase: No programmable Thermostat

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (7%), incremental cost ($150, adjusted for inflation) and measure life (15 yrs) from ACEEE 1994.

Steam Trap Maintenance (Natural Gas Only)

Measure Description: Annual maintenance of steam traps to allow condensate, air & CO2 out of the steam system while minimizing steam loss.

Basecase: No steam trap maintenance

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (3%), measure life (1 yr) and incremental cost ($3.33 per MMBtu of savings) from NYSERDA 2006. Percent applicable (33%) equal to households heating with natural gas that use steam boilers.

Exhaust Fan Timers (Electricity Only)

Measure Description: Install timer switch on exhaust fans.

Basecase: Furnace fans (heating and cooling) without exhaust fan timers.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Percent applicable (100%) equal to households with exhaust fans.

Mainline Air Vents (Natural Gas Only)

Measure Description: Installation of new, larger vents to allow for even distribution of heating between units close to and furthest from steam system.

Basecase: Lack of mainline air vents.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Percent savings (10%), measure life (30 yrs) and incremental cost ($83, adjusted for inflation) from ACEEE 1994. Market share (25%) from PA oil analysis. Percent applicable (33%) equal to households heating with natural gas that use steam boilers.

Thermostatic Steam Valves (Natural Gas Only)

Measure Description: Installation of steam valves to regulate steam flow when setpoint temperature has been reached, maintaining balance and minimizing excess heat distribution.

Basecase: Steam heating system without thermostatic steam valves

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Baseline consumption also adjusted upwards by ratio between system efficiencies for hydronic and steam systems (.799/.5002 = 1.597) to account for additional consumption required in steam system due to distribution losses (ACEEE 1994). Savings (6%) and incremental cost ($239) from ACEEE 1994. Market share (40%) from PA oil analysis. Percent applicable (33%) equal to households heating with natural gas that use steam boilers.

Improved Heating System, High Efficiency Unit, Tier 1 (Natural Gas Only)

Measure Description: Upgrade heating system to condensing heating system.

Basecase: Standard heating system.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Percent savings (6%, average of upstate and downstate) and measure life (25 yrs) from NYSERDA 2006. Incremental cost ($425, adjusted for inflation, split across 39 units (from RECS micro data)) from ACEEE 1994. Market share (40%) from PA oil analysis.

Front End Boiler (Natural Gas Only)

Measure Description: Involves replacing the first boiler in a series, front-end boiler, with a high-efficiency condensing boiler. This boiler is utilized throughout the heating season for multifamily buildings.

Basecase: Non-condensing front-end boiler.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (50%) from ASHRAE 2006. Incremental cost ($84 = $3267 spread over 39 units) from Sachs et al. 2004. Market share (9%, average of low-rise buildings, p.2-37) from ACEEE 1994. Percent applicable (33%) equal to households heating with natural gas that use boilers.

Steam Boiler (Natural Gas Only)

Measure Description: New steam boiler with 82% AFUE

Basecase: Steam boiler with 75% AFUE

Measure Description: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Baseline consumption also adjusted upwards by ratio between system efficiencies for hydronic and steam systems (.799/.5002 = 1.597) to account for additional consumption required in steam system due to distribution losses (ACEEE 1994). Savings (9%) equal to increase in AFUE (.7/.82). Incremental cost ($392 = $15,289 spread over 39 units) from ACEEE 1994. Percent applicable (33%) equal to households heating with natural gas that use boilers.

Efficient Room Air Conditioner (Electricity Only)

Measure Description: Energy Star Room A/C (10000 Btu unit at 10.8 EER).

Basecase: Room A/C that meets 2000 federal energy standards (10000 Btu at 9.8 EER)

Data Explanation: Baseline consumption and incremental cost ($30) from Energy Star savings calculator. Savings (17%) calculated by increase in EER. Percent homes applicable (48%) based on number of homes with Room A/C unit from RECS 2005 (EIA 2008). Measure life (13 years) from Sanchez, et al, 2007. Market share (51%) from Energy Star 2006 appliance sales data specific to Pennsylvania (EPA 2007).

Refrigerator Tier I (Electricity Only)

Measure Description: Replacement refrigerator that meets 2008 ENERGY STAR requirements (20% better than federal standard)

Basecase: Refrigerator that meets current 2001 federal energy standards.

Data Explanation: Baseline consumption, incremental cost ($64) and measure life (19 years) from ACEEE analysis for PG&E/CA Title 24 (PG&E, 2007). Market share (28%) from Energy Star 2006 appliance sales data specific to Pennsylvania (EPA 2007).

Condensing Gas Storage Water Heater (Natural Gas Only)

Measure Description: 50-gallon natural gas storage water heater, 0.86 EF

Basecase: Current federal standard for typical, 50-gallon natural gas storage water heater, 0.59 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (31%) from ratio of EF increase (.27/.86).

Incremental cost ($19 = $1150 split across 39 units (from RECS micro data)) and measure life (13 yrs) from Amann, et al., 2007. Percent applicable (63%) equivalent to houses with natural gas water heaters (EIA 2008).

Efficient Dishwasher (appliances, electricity only))

Measure Description: Dishwasher meeting 2011 Energy Star requirement of 0.72 EF

Basecase: Dishwasher meeting 2010 federal energy standard of 0.62 EF

Data Explanation: Baseline consumption (200 kWh/yr) assumes 215 cycles/yr at .93 kWh per cycle, apportioned for appliance electricity use, from DOE 2007. Incremental cost ($8) and electricity savings from DOE 2007 Technical Support Document, isolating appliance energy savings only. Incremental cost apportioned based off ratio of electricity savings between the appliance and electricity used for water heating. Measure life (13 years) is from Sanchez, et al, 2007. Market share (15%) from April 2007 LBL analysis on the AHAM-efficiency advocate agreement.

Efficient Dishwasher (water heating, electricity only)

Measure Description: Dishwasher meeting 2011 Energy Star requirement of 0.72 EF

Basecase: Dishwasher meeting 2010 federal energy standard of 0.62 EF

Data Explanation: Baseline consumption (146 kWh) assumes 215 cycles/yr at .68 kWh per cycle, apportion for water heating use, from DOE 2007. Incremental cost ($22) and energy savings from DOE 2007 Technical Support Document, isolating water heating energy savings only. Incremental cost apportioned based off ratio of electricity savings between the appliance and electricity used for water heating. Measure life (13 years) is from Sanchez, et al, 2007. Market share (15%) from April 2007 LBL analysis on the AHAM-efficiency advocate agreement.

Dishwasher (Natural Gas Only)

Measure Description: Dishwasher meeting 2011 Energy Star requirement of 0.72 EF

Basecase: Dishwasher meeting 2010 federal energy standard of 0.62 EF

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (14%) from EF increase (.10/.72). Incremental cost ($22) from DOE 2007, isolating water heating energy savings only (of $30 total incremental cost). Market share (15%) from April 2007 LBL analysis on the AHAM-efficiency advocate agreement.

Horizontal-Axis Clothes Washer (water heating, electricity only)

Measure Description: Front-loading (H-axis) clothes washer meeting ENERGY STAR requirements (2.0 MEF)

Basecase: Federal standard for clothes washers: 1.26 MEF

Data Explanation: Baseline consumption and savings (31%) from EPA 2008a, isolating water heating energy savings only. Incremental cost ($147) apportioned based on percentage of electricity consumption dedicated to water heating less savings from decreased water usage ($33), from EPA 2008. Percent applicable (100%) based on appliance saturation data from RECS 2005 (EIA 2008). 2006 market share (36%) from EPA 2007. Measure life (14 years) is from Sanchez, et al, 2007.

Horizontal-Axis Clothes Washer (appliances, electricity only)

Measure Description: Front-loading (H-axis) clothes washer meeting ENERGY STAR requirements (2.0 MEF)

Basecase: Federal standard for clothes washers: 1.26 MEF

Data Explanation: Baseline consumption and savings (31%) from EPA 2008a, isolating appliance energy savings only. Incremental cost ($20) apportioned based on percentage of electricity consumption not dedicated to water heating. Percent applicable (100%) based on appliance saturation data from RECS 2005 (EIA 2008). 2006 market share (36%) from EPA 2007. Measure life (14 years) is from Sanchez, et al, 2007.

Commercial Clothes Washer (Natural Gas Only)

Measure Description: Front-loading (H-axis) clothes washer meeting 2011 ENERGY STAR requirements (2.0 MEF)

Basecase: Federal standard, EF = 1.26

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Incremental cost ($10 = $400 split across 39 units (from RECS micro data)) and savings (36%) from PA commercial analysis. Market share (20%) from DOE 2007.

Faucet Aerator (Natural Gas Only)

Measure Description: 1.5 gallons per minute (gpm) faucet aerator

Basecase: Assumes gas water heater meeting current federal standard (see Electric Storage Water Heater above). Baseline aerator meets federal requirements of 2.5 gpm

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (5.5%) equals half of the average of three home types (colonial, ranch, wood-frame) of savings for both showerheads and faucet aerators (11%), from ACEEE 1994 (p.2-50). Cost estimate ($7) for a low-cost, basic model from the DEER database (CEC 2005). Measure life (10 yrs) from ACEEE 1994. Market share (30%) from PA oil analysis.

Low-flow Showerheads (Natural Gas Only)

Measure Description: 2.0 gallons per minute (gpm) showerhead

Basecase: Assumes gas water heater meeting current federal standard (see Electric Storage Water Heater above). Showerhead meets federal requirements of 2.5 gpm

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (5.5%) equals half of the average of three home types (colonial, ranch, wood-frame) of savings for both showerheads and faucet aerators (11%), from ACEEE 1994 (p.2-50). Cost estimate ($23) for a low-cost, basic model from the DEER database (CEC 2005). Measure life (10 yrs) from ACEEE 1994. Market share (30%) from PA oil analysis.

Pipe Insulation (water heating, natural gas only)

Measure Description: Insulation of piping for water heating.

Basecase: Uninsulated pipes.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Measure life (15 yrs) from NYSERDA 2006. Savings (10%) from ACEEE 1994. Incremental cost ($100) and market share (50%) from PA oil analysis.

Pump/Demand Controller (Natural Gas Only)

Measure Description: Installation of electronic control that memorizes building hot water demand patterns and reduces hot water loop temperatures during periods of low hot water demand.

Basecase: No pump/demand controller installed.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (16%), incremental cost ($43 = $1400, adjusted for inflation, spread over 39 units) and measure life (15 yrs) from ACEEE 1994. Market share (40%) from PA oil analysis.

Graywater Heat Exchanger (Natural Gas Only)

Measure Description: Installation of GWHX that recycles hot "gray" water from showers, sinks, etc. to heat water for space heating.

Basecase: No GWHX installed.

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Savings (40%, average of upstate and downstate) and incremental cost ($230, $80.22 per unit of savings) from NYSERDA 2006. Percent applicable (20%) from NYSERDA 2006.

Oven w/ electric ignition (Natural Gas Only)

Measure Description: Installed electric ignition, improved insulation and improved door seals give EF = 0.062.

Basecase: Conventional range with an oven EF = 0.059

Data Explanation: Baseline consumption from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008) and by end-use split (AEO 2007). Incremental cost ($40) from DOE 2006. Savings (20%) from Amann, et al. 2007 (p.160). Measure lifetime (18 yrs) from Appliance 2007.

Retrocommissioning (Natural Gas Only)

Measure Description: Optimization of existing buildings energy usage and equipment through better operation and maintenance, control calibration, facility staff training, etc.

Basecase: No retrocommissioning

Data Explanation: Baseline consumption equal to sum of space heating and water heating natural gas consumption, from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008). Savings (6%), measure life (7 yrs), and incremental cost ($76, average of upstate and downstate costs, given as dollars per unit savings) from NYSERDA 2006.

Integrated Design (30% > Codes) Tier 1 (Natural Gas Only)

Measure Description: Integrated building design that is 30%> than current Pennsylvania code.

Basecase: Building that meets current Pennsylvania code.

Data Explanation: B Baseline consumption equal to sum of space heating and water heating natural gas consumption, from RECS 2001 (EIA 2003) adjusted by percent of PA multifamily building stock (Economy.com 2008). Savings (30%), measure life (50 yrs), and incremental cost ($171.56, average of upstate and downstate costs, given as dollars per unit savings) from NYSERDA 2006.

Active Mode Efficiency for Televisions (Electricity Only)

Measure Description: Energy Star Television Specification, Version 3.0

Basecase: Average of all TVs from ENERGY STAR data set (CEE 2008).

Data Explanation: Baseline consumption, new measure consumption, measure life (6 yrs), and savings from CEE 2008.

Low Power Set-Top Boxes (Electricity Only)

Measure Description: Require digital set-top boxes to have a maximum sleep state power level of 10 watts and to automatically enter sleep mode after 4 hours without user input.

Basecase: Typical house with 1.9 set top boxes (Rainer, 2008).

Data Explanation: All data except cost from Rainer 2008. No reliable incremental cost data is available. In the case of set-top boxes, efficiency measures are largely software-related, likely resulting in very low cost per kWh saved per household. Our cost estimte is set to result in a levelized cost similar to that for TVs.

One-Watt Standby for All Household Electronics (Electricity Only)

Measure Description: All new electronics devices required to have maximum “off” mode power level of 1 watt.

Basecase: Typical house with 15 devices that consume 50 watts standby power.

Data Explanation: Baseline consumption, savings, incremental costs and measure life available from ACEEE 2004 emerging technologies analysis (Sachs et al. 2004). Penetration of new measure assumed by averaging market shares of all ENERGY STAR home electronics equipment.

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Commercial Buildings

Electric Analysis

Baseline End-Use Electricity Consumption

To estimate the resource potential for efficiency in commercial buildings in Pennsylvania, we first develop a disaggregate characterization of baseline electricity consumption in the state for current electricity use and a reference load forecast (see Table B-8 below). Highly disaggregated commercial electricity consumption data is unfortunately not available at the state level. To estimate these data, we start with current electricity consumption for the Pennsylvania commercial sector (EIA 2008) and a forecast out to 2025 based on PJM forecasts, and we disaggregate by end-use using average regional data from CBECS 2003 (EIA 2006) and AEO 2007 (EIA 2007).

Table B-8. Baseline Commercial Electricity Consumption by End-Use (GWh)

End-Use	2009	%	2015	%	2025	%
Heating	1,930	4%	2,120	4%	2,260	4%
Cooling	4,990	10%	5,480	10%	6,200	10%
Ventilation	*2,350*	*5%*	*2,580*	*5%*	*2,860*	*5%*
HVAC subtotal	9,280	19%	10,190	19%	11,320	18%
Water Heating	1,260	3%	1,380	3%	1,410	2%
Refrigeration	3,440	7%	770	7%	4,210	7%
Lighting	17,790	36%	,540	36%	21,850	35%
Office Equipment	6,930	14%	7,610	14%	9,830	16%
Other	10,180	21%	11,180	21%	14,110	23%
Total	48,870	100%	53,670	100%	62,720	100%

Next, we estimate commercial square footage in the state using electricity intensity data (kWh per square foot) by census region from CBECS (EIA 2006). We use the Mid Atlantic census region to estimate overall electricity intensity for the state of Pennsylvania of 12.5 kWh per square foot. Total electricity consumption in the state divided by the electricity intensity provides an estimate of commercial floorspace. Using this methodology, we estimate 3,910 million square feet of commercial floorspace in the state.

Measure Cost-Effectiveness

We then analyze 34 efficiency measures for existing commercial buildings and 3 new construction whole-building measures to examine the cost-effective energy efficiency resource potential. For each efficiency measure, we estimate electricity savings (*Annual Savings per Measure)* and incremental cost (*Measure Cost)* in a "replacement on burnout scenario," which assumes that the product is replaced or the measure is installed at the end of the measure's useful life. Savings and costs are incremental to an assumed *Baseline Measure*. We estimate savings (kWh) and costs ($) on a per-unit and/or a per-square foot commercial floorspace basis. For each measure we also assume a *Measure Lifetime*, or the estimated useful life of the product.

A measure is determined to be cost-effective if its levelized cost of saved energy, or cost of conserved energy (CCE), is less than 9.18 cents/kWh, the estimated current average commercial cost of electricity in Pennsylvania. The estimated CCE for each efficiency measure, which assume a discount rate of 5%, are shown in the measure descriptions below. Equation 1 shows the calculation for cost of conserved energy.

Our assumed *Baseline Measure*, *Annual Savings per Measure, Measure Cost, Measure Lifetime, and CCE* are reported for each of the efficiency measures in the list of measure descriptions below. We group the 34 efficiency measures for existing commercial buildings by end-use and list the 3 new building measures last.

Equation 1. CCE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure (kWh))

Total Statewide Resource Potential

For each measure, we then derive *Annual Savings per Measure* on a per square foot basis *(kWh per square foot)* for the applicable end-use. For measures that we only have savings on a per-unit or per-building basis, we first derive the percent savings and multiply by the *Baseline Electricity Intensity* for that end-use. The assumed baseline intensities for each end use are shown in Table B-9. As an example, for a specific lighting measure we multiply its percent savings by the baseline electricity intensity (kWh per square foot) for the lighting end-use.

Table B-9. Commercial End-Use Baseline Electricity Intensities (kWh per s.f.)

End Use	kWh	MBtu
Heating	0.5	1.7
Cooling	1.3	4.4
Ventilation	0.6	2.1
Water Heating	0.3	1.1
Cooking	0.1	0.2
Lighting	4.6	15.5
Refrigeration	0.9	3.0
Office Equipment	1.8	6.0
Other	2.6	8.7
HVAC Subtotal	2.4	8.1
Total	12.5	42.7

To estimate the total efficiency resource potential in existing commercial buildings in Pennsylvania by 2025, we must first adjust the individual measure savings by an *Adjustment Factor* (See Equation 2). This factor accounts for two adjustments: the technical feasibility of efficiency measures, called the *Percent Applicable* (the percent of Pennsylvania floorspace that satisfy the base case conditions and other technical prerequisites such as heating fuel type and cooling equipment, etc); and the *Current Market Share*, or the percent of products that already meet the efficiency criteria. These assumptions are outlined in each of the efficiency measure descriptions below.

Equation 2. Adjustment Factor = Percent Applicable x (1-Current Market Share).

We then adjust total savings for interactions among individual measures. For example, we must adjust HVAC equipment savings downward to account for savings already realized through improved building envelope measures (insulation and windows), which reduce heating and cooling loads. Similarly, we adjust water heating equipment savings to account for reduced water heating loads from the use of more efficient clothes washers. The multiplier for these adjustments is called the *Interaction Factor.*

Finally, we adjust replacement measures with lifetimes more than 7 and 17 years to only account for the percent turning over in 7 and 17 years, which represents the benchmark years of 2015 and 2025, respectively. Note that the multiplier, *Percent Turnover,* is only applicable to products being replaced upon burnout and not retrofit measures such as insulation. These retrofit measures therefore have 100% of measures “turning over.”

We then calculate the resource potential for each measure in the state using Equation 3, which takes into account all of the adjustments described above. The sum of the resource potential from all measures is the overall energy efficiency resource potential in the state's commercial buildings sector.

Equation 3. Efficiency Resource Potential in 2015 and 2025 (GWh) = (Annual Savings per Measure (kWh per square foot)) x (Commercial floor space in Pennsylvania in millions of square feet) x (Percent Applicable) x (Interaction Factor) x (Percent Turnover)

Efficiency Measures

Table B-10 shows the thirty-seven efficiency measures examined for this analysis, grouped by end-use costs, savings (kWh) per product or square foot, *Percent Applicable, Interaction Factor, Percent Turnover,* and total savings potential (GWh) in 2025. Detailed descriptions of each measure are given below, grouped by end-use.

Building Shell Improvements

Cool roof

Measure Description: This measure involves installing a sun-reflective coating on the roof of a building with a flat top. This reduces air conditioning energy loads by reducing the solar energy absorbed by the roof.

Basecase: The baseline electricity intensity for HVAC end uses in Pennsylvania (2.4 kWh/ft^2/year) is used as the basecase.

Data Explanation: We assume 4% HVAC load savings (ACEEE 1997) off the baseline electricity intensity for HVAC end-uses in Pennsylvania (EIA 2006), an incremental cost of $0.25 per ft^2 (SWEEP 2002), and a 20-year average lifetime (SWEEP 2002). Percent applicable (80%) is an ACEEE estimate. Savings and cost per unit are based on a 15,000 ft^2 building from ACEEE Mid-Atlantic study (1997). The levelized cost is calculated to be 5.5 cents/kWh.

Roof insulation

Measure Description: Fiberglass or cellulose insulation material in roof cavities will reduce heat transfer, though the type of building construction limits insulation possibilities. R-values describe the performance factor for insulation levels.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percentage of savings.

Data Explanation: We assume 3% savings and a post-savings electricity intensity of 0.28 kWh/ft^2/year, based on an average of four building types (ACEEE 1997). An average lifetime of 25 years (CL&P 2007) and an incremental cost of 12 cents/ft^2 were also assumed. The measure is shared with gas savings as well, so the portion of the incremental cost attributed to electric savings is 7 cents/sf. The levelized cost is 18 cents/kWh.

Double Pane Low-Emissivity Windows

Measure Description: Double-pane windows have insulating air- or gas-filled spaces between each pane, which resist heat flow. Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer back through the window, and a window's R-value represents the amount of heat transfer back through a window. Low-e windows are particularly useful in climates with heavy cooling loads, because they can reflect anywhere from 40% to 70% of the heat that is normally transmitted through clear glass. The Solar Heat Gain Coefficient (SHGC) represents the fraction of solar energy transferred through a window. For example, a low-e window with a 0.4 SHGC keeps out 60% of the sun's heat.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percent savings.

Data Explanation: Percent savings of 3% apply to whole-building electricity consumption (ACEEE 1997). Incremental costs assume $2 per window (SWEEP 2002). This measure is shared with gas savings as well. A measure life of 25 years is from SWEEP 2002. Percent applicable is an ACEEE estimate. The levelized cost is calculated to be 1.8 cents/kWh.

Heating and Cooling Measures: Equipment and Controls

Duct testing and sealing

Measure Description: Testing and sealing air distribution ducts saves energy. This measure assumes supply and return ducts will be fully sealed.

Basecase: The basecase assumes air loss of 29% of fan flow, and leakage of 15% of the system flow.

Data Explanation: Percent savings of 6% apply to whole-building electricity consumption (SWEEP 2002). An incremental cost of $3,375, which assumes $300 per ton, a 10 year lifetime, and 25% applicability are ACEEE estimates. The levelized cost is calculated to be 1.8 cents/kWh.

Primary air-handler fans with Variable-Frequency Drive

Measure Description: Variable Frequency Drive (VFD) controls the speed of a motor by adjusting the frequency of incoming power. By controlling the speed of a motor, the output of the system can be matched to the requirements of the process, thereby improving efficiency.

Basecase: The basecase unit is a 50 hp fan with 60% load factor, 93% efficiency (ODP, EPAct levels) and 3653 operating hours/year (21-50 hp category from ACEEE standards savings analysis).

Data Explanation: We assume 25% savings applies to ventilation only (ACEEE 1997), which is a conservative estimate. We estimate a $6,650 incremental cost, which assumes $125/hp for VFD and $8/hp for a better fan, and a 10-year measure life (SWEEP 2002). ACEEE estimates that this measure can apply to 40% of systems. The levelized cost is calculated to be 3.9 cents/kWh.

High-Efficiency Unitary AC/HP

65,000 Btu — 135 Btu
135,000 Btu — 240,000 Btu

Measure Description: Unitary packaged air conditioners and heat pumps represent the heating, ventilating, and air conditioning (HVAC) equipment class with the greatest energy use in the commercial sector in the United States, and are used in approximately 48 percent of the cooled floor space in the commercial sector (DOE 2004). High efficiency units have a greater energy efficiency ratio (EER).

Basecase: The assumed basecase unit meets the 2010 federal efficiency standard. Baseline electricity intensity for this end-use, 3 kWh per ft^2, is the estimated HVAC consumption in commercial buildings in Pennsylvania. This is data from the Mid Atlantic from EIA's commercial buildings survey (EIA 2006).

Data Explanation: This measure includes two size ranges; the first is 65,000 Btu to 135,000 Btu, and the second is 135,000 Btu to 240,000 Btu. The measure assumes a 12 EER unit relative to the 2010 federal standard, which ranges from about 10.4 EER to 11.2 EER, depending on the unit type and size. The energy savings average 1,070 kWh (7.2%) for the smaller unit and 3,371 kWh (10.8%) for the larger unit. We assume a measure lifetime of 15 years (LBNL 2003). Incremental costs (average $629 for 65 kBtu to135 kBtu and $1,415 for 135 kBtu to 240 kBtu) are derived from DOE's Technical Support Document (DOE 2004). Percent applicable (33% for 65 kBtu to135 kBtu), and the percent of floorspace with cooling from unitary equipment are also from DOE's Technical Support Document (DOE 2004). The levelized cost is calculated to be 4–5.7 cents/kWh, depending on unit type and size.

High-Efficiency Packaged Terminal AC/HP

Measure Description: PTACs and PTHPs are self-contained heating and air-conditioning units encased inside a sleeve specifically designed to go through the exterior building wall. The basic design of a PTAC is comprised of a compressor, an evaporator, a condenser, a fan, and an enclosure. They are primarily used to provide space conditioning for commercial facilities such as hotels, hospitals, apartments, dormitories, schools, and offices. High-efficiency units have a higher energy efficiency ratio (EER) for cooling units and coefficient of performance (COP) for heat pumps.

Basecase: Consistent with all HVAC-related measures, the baseline electricity intensity is 2.4 kWh per ft^2, which is the estimated HVAC consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume that high efficiency units save an average of 7.8%, or 226 kWh per unit, relative to a basecase, which is based on an ACEEE submission to ASHRAE using web data. The measure life is 15 years (ANSI/ASHRAE 1999). Percent applicable is 5%, which is the percent of cooling floorspace from packaged terminal units (ADL 2001). The levelized cost is calculated to be 3.8 cents/kWh.

Efficient Room Air Conditioner

Measure Description: An Energy Star room AC must be at least a 10% improvement over the 2000 federal standard (an average 8000 Btu unit must have a 10.8 EER).

Basecase: The assumed basecase unit is a room A/C that meets 2000 federal energy standards (an average 8000 Btu unit has a 9.8 EER) and uses an average of 1212 kWh per unit. Baseline electricity intensity for this end-use, 1.3 kWh per ft^2, is the estimated cooling consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume an Energy Star room AC uses 1100 kWh per year, saves 9% of basecase energy, and has an incremental cost of $30 (Energy Star calculator). We assume a measure life of 9 years (Energy Star calculator), a current market share of 52% (EPA 2007), and percent applicable assumes 4% percent of cooling floorspace uses room AC units (ADL 2001). The levelized cost is calculated to be 4.3 cents/kWh.

High-Efficiency Chiller

Measure Description: "Chillers" are the hearts of very large air-conditioning systems for buildings and campuses with central chilled water systems. A centrifugal chiller utilizes the vapor compression cycle to chill water and reject the heat collected from the chilled water plus the heat from the compressor to a second water loop controlled by a cooling tower.

Basecase: The basecase unit assumes 0.634 kW/ton T24 from DEER for an average 150 ton system and 1,593 national average full-load operating hours from the ASHRAE 90.1-1999 analysis. Baseline electricity intensity for this end-use, 2.4 kWh per ft^2, is the estimated HVAC consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume the new measure has 20% savings, which is derived from estimates provided in SWEEP 2002 and ACEEE 1997. The lifetime estimate of 23 years is from the ASHRAE Handbook (HVAC Applications). Incremental costs are $9,900 and assume a 150 ton average unit (CEC 2005). Percent applicable (33%) assumes percentage of cooling floorspace using chillers (ADL 2001). The levelized cost is calculated to be 2.4 cents/kWh.

Dual-Enthalpy Economizer

Measure Description: Economizers modulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy, or the latent and sensible heat, of the outside air is less than that of the return air when space cooling is required, then the outside air is allowed to reduce or eliminate the cooling requirement of the AC equipment.

Basecase: Baseline electricity intensity, 3 kWh per ft^2, is the estimated HVAC consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: Savings per unit assume 276 kWh (20% savings) per ton for an average 11-ton unit (CL&P 2007). Average measure life is 10 years (CL&P 2007). Incremental costs per unit are from NYSERDA 2003. Percent applicable is the portion of cooling square footage represented by packaged AC and HP units, and assumes that 90% of these unitary systems could benefit from economizers (ACEEE estimate). It also assumes a 5% current market share (ACEEE estimate). The levelized cost is calculated to be 3.8 cents/kWh.

Demand-Controlled Ventilation

Measure Description: Often, HVAC systems are designed to supply ventilated air based on assumed occupancy levels, resulting in over-ventilation. Demand-controlled ventilation monitors CO_2 levels in different zones and delivers the required ventilation only when and where it is needed.

Basecase: The basecase is standard ventilation electricity consumption for a 50,000 ft^2 office building, or about 40,000 kWh/year (Sachs et al. 2004). Baseline electricity intensity for this end-use, 0.6 kWh per ft^2, is the estimated ventilation consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume 20% savings for this measure (Sachs et al. 2004). Energy use per unit is 32,000 kWh/year, assuming a 50,000 ft^2 building (Sachs et al. 2004). The lifetime estimate is 15 years, and incremental costs are $3,450 (Sachs et al. 2004). The measure is applicable to 90% of larger (60%) cooling units (Sachs et al. 2004). The levelized cost is calculated to be 4.2 cents/kWh.

HVAC Tune-up

Measure Description: Most HVAC technicians lack interest, training, equipment and methods to perform quality refrigerant charge and airflow (RCA) tune-ups. Because many new and existing air conditioners have improper RCA, which reduces efficiency, there is significant potential for energy savings by diagnosing and correcting RCA.

Basecase: The assumed basecase unit is a 4.5 ton commercial unitary AC/HP per California program experience (CPUC 2006), estimated to use 8,396 annual kWh per the unitary AC/HP measure. The base electricity intensity for the HVAC end-use is 2.3 kWh/ ft^2, the average for small buildings less than 25,000 ft^2, for which this measure is applicable.

Data Explanation: We assume 11% percent savings from this measure according to California's DEER database (CEC 2005) and the California Refrigerant and Air Charge (RCA) program report (CPUC 2006). We assume that 60% of units have improper RCA (CPUC 2006), and therefore this measure is applicable to 60% of unitary HVAC units in buildings less than or equal to 25,000 ft^2 (EIA 2006; average of south and mid-Atlantic regions). We estimate an average measure life of 3 years, as units need to be periodically re-tuned. We assume a cost of $158 for this measure, based on a $35/ton labor cost (CEC 2005) and an assumed 4.5-ton unit. The levelized cost is calculated to be 6.3 cents/kWh.

Energy Management System (EMS)

Measure Description: An Energy Management System (EMS) is a computerized system that collects, analyzes and displays information on HVAC, lighting, refrigeration, and other commercial building subsystems to aid commercial building and facility energy managers, financial managers, and electric utilities in reducing energy use in buildings.

Basecase: Baseline electricity intensity is the average HVAC end-use consumption in Pennsylvania, estimated from CBECS (EIA 2006b) to be the average of consumption in the Mid-Atlantic region.

Data Explanation: We assume 10% cooling savings and 7.5% heating and ventilation savings from an installed EMS (NYSERDA 2003). We estimate a 15-year measure life for the system. We assume total incremental costs of $19,333 for a 60,000 ft^2 building, which is derived from NYSERDA 2003, and assume a third of this ($6,380) for this measure by assuming the cost is spread equally among electric HVAC, gas HVAC and lighting. Percent applicable is an ACEEE estimate. The levelized cost is calculated to be 6.6 cents/kWh.

Retrocommissioning

Measure Description: Commercial building performance tends to degrade over time, and many new buildings do not perform as designed, requiring periodic upgrades to restore system functions to optimal performance. Retrocommissioning (RCx) is a systematic process to optimize building performance through O&M tune-up activities and diagnostic testing to identify problems in mechanical systems, controls, and lighting. The best candidates for RCx are buildings over 50,000 or 100,000 ft2.

Basecase: The baseline is electricity intensity for HVAC and lighting end-uses in buildings greater than 50,000 ft2 (10 kWh/ ft2), which is based on data from CBECS (EIA 2006). We take the average of the Mid-Atlantic region to estimate electricity intensity in Pennsylvania buildings.

Data Explanation: We assume 10% savings for HVAC and lighting end-uses (Sachs et al. 2004) in all commercial floorspace for buildings greater than 100,000 ft2, and 50% of floorspace in buildings 50,000 ft2 or greater based on data from CBECS (EIA 2006). Xcel Energy's RCx program results estimate an average RCx useful life of 7 years (Xcel Energy 2006). We assume a $0.25 cost per ft2 (Sachs et al. 2004). The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.10. The levelized cost is calculated to be 2.8 cents/kWh.

Water Heating Measures

Heat Pump Water Heater

Measure Description: A heat pump water heater uses electricity to move heat from one place to another, rather than a less efficient electric resistance water heater which uses electricity to generate the heat directly. The heat source is the outside air or air in the basement where the unit is located.

Basecase: The basecase is standard electric water heating, with electricity consumption of 22,831 kWh/year (derived from energy savings and percent savings). Baseline electricity intensity for this end-use, 0.32 kWh per ft^2, is the estimated water heating consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: We assumed a 50% savings, based on a simple coefficient of performance ratio. The assumed 14,155 kWh savings, $4,067 incremental cost, and 12 year lifetime estimates are from NYSERDA 2003. Percent applicable is based on engineering estimates for NYSERDA 2003, which assumes the measure is applicable to 70% of food service floorspace and 30% of lodging, education, and health care floorspace. Percent applicable is then multiplied by 2, since these building types are more energy and hot-water intensive than the average commercial building. The levelized cost is calculated to be 3.2 cents/kWh.

Efficient Commercial Clothes Washer (water heating portion)

Measure Description: A high-efficiency commercial clothes washer saves both energy and water, and as a result reduces water heating loads. For a high-efficiency clothes washer, we assume a unit with an MEF of 2.0, which represents about 80% of products on Energy Star's product lists.

Basecase: The basecase unit is a clothes washer that meets DOE's federal efficiency standard of 1.26 MEF. An average unit consumes 1,136 kWh annually for water heating, which is derived from DOE (2007). Baseline electricity intensity for this end-use is 0.32 $kWh/ft^2/year$ (water heating portion only).

Data Explanation: Savings on electric water heating from this measure assume a 2.0 MEF clothes washer uses an average 431 kWh annually, for a 62% savings, which is derived from DOE's TSD (DOE 2007). We assume the measure is applicable to the 17% of units that have electric water heating, and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Pennsylvania based on commercial building floorspace. We assume an incremental cost for an efficient unit is $316 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 3.7 cents/kWh.

Refrigeration Measures

Efficient Walk-In Refrigerators & Freezers

Measure Description: Walk-in refrigerators and freezers (walk-ins) are medium and low-temperature refrigerated spaces that can be walked into, and that are used to maintain the temperature of pre-cooled materials (not to rapidly cool down materials from warmer temperatures). A high-efficiency walk-in is defined as meeting the 2004 CEC standard for walk-ins. This includes prescriptive requirements such as higher levels of insulation, motor types, and the use of automatic door-closers (Nadel et al. 2006).

Basecase: The baseline energy use for an average walk-in is 18,859 kWh/year (Nadel et al. 2006). Baseline electricity intensity for this end-use, 0.88 kWh per ft^2, is the estimated refrigeration energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: For a high-efficiency walk-in unit, we assume 44% savings over a baseline unit, or 8220 kWh/year, $957 incremental cost, and a 12 year measure lifetime (Nadel et al. 2006), which are based on a PG&E CASE study (2005). We estimate percent applicable as the 18% of refrigeration energy use attributed to walk-ins (ADL 1996) and estimate a 50% current market share of high-efficiency products (ACEEE estimate). The levelized cost is calculated to be 1.3 cents/kWh.

Efficient Reach-In Coolers & Freezers

Measure Description: This measure includes high-efficiency packaged commercial reach-in refrigerators and freezers with solid doors, and refrigerators with transparent doors such as beverage merchandisers. High-efficiency units are those that meet the CEE Tier 2 performance standard, as estimated in PG&E 2005.

Basecase: We assume a baseline unit, which is one that meets that upcoming (2009 or 2010) federal standard, uses 4,027 kWh per year. This is weighted by sales of unit type per PG&E 2004. Baseline electricity intensity for this end-use, 0.88 kWh per ft^2, is the estimated refrigeration energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: The savings estimate for a high-efficiency unit, 31% savings or 1,268 kWh per year, is a weighted average of different types of reach-ins that meet CEE's Tier 2 performance standard (PG&E 2005). We estimate an average lifetime of 9 years and an incremental cost of $341, both per PG&E 2005. We estimate percent applicable as the percent of refrigeration energy use attributed to reach-ins and beverage merchandisers, or 17% (ADL 1996), and assume a 10% current market share of high-efficiency products per PG&E 2005. The levelized cost is calculated to be 2.0 cents/kWh.

Efficient Ice-Maker

Measure Description: Commercial ice makers, which are used in hospitals, hotels, and food service and preservation, have energy savings potential largely in their refrigeration systems. We assume an efficient icemaker meets CEC's Tier 2 level of energy savings, which incorporate improved compressors, heat exchangers, and controls, as well as better insulation and gaskets.

Basecase: The baseline energy use, 3,338 kWh per year, is a weighted average of different types of ice-makers that meet the 2010 standard. Baseline electricity intensity for this end-use, 0.88 kWh per ft^2, is the estimated refrigeration energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: The 16% savings estimate for a high-efficiency unit, or 542 kWh per year, is a weighted average of different types of ice-makers that meet CEC's tier 2 energy savings (PG&E 2005). We estimate an average lifetime of 10 years and an incremental cost of $100, both per PG&E 2005. We estimate percent applicable as the percent of refrigeration energy use attributed to ice-makers, or 10% (ADL 2006), and assume a 10% current market share of high-efficiency products per PG&E 2005 and ACEEE judgment. The levelized cost is calculated to be 2.4 cents/kWh.

Efficient Built-up Refrigeration System

Measure Description: Built-up or supermarket refrigeration systems are primarily made up of refrigerated display cases for holding food for self-service shopping, as well as machine room cooling technologies. More efficient built-up systems include improved machine room technologies (evaporative condensers, mechanical sub-cooling, and heat reclaim), high-efficiency evaporative fan motors, hot gas defrost, liquid-suction heat exchangers, antisweat control, and defrost control.

Basecase: The measure baseline is 1,600,000 kWh for a 45,000 ft^2 supermarket with a built-up refrigeration system. Baseline electricity intensity for this end-use, 0.88 kWh per ft^2, is the estimated refrigeration energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: Per-unit savings of 336,000 kWh (21%) are from ADL 1996 and assume an average new 45,000 ft^2 supermarket with a 5-year payback. We estimate percent applicable as the percent of refrigeration energy use attributed to built-up refrigeration, or 33% (ADL 1996). Incremental cost ($37,000) and lifetime (10 years) are from ADL 1996. The levelized cost is calculated to be 1.4 cents/kWh.

Efficient Vending Machine

Measure Description: Energy Star vending machines must consume 50% less energy than standard machines. Under the Tier II ENERGY STAR level, this translates to a maximum energy consumption of 6.53 kWh/day for a 650-can machine.

Basecase: A Tier I ENERGY STAR level vending machine is assumed to be the basecase. On average, it uses 2,816 kWh per year (Energy Star calculator for a 600 can machine). Baseline electricity intensity for this end-use, 0.88 kWh per ft^2, is the estimated refrigeration energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: Per unit savings of 18% (509 kWh/year) are estimated from ASAP 2007 based on Energy Star calculator estimates. Likewise, an incremental cost of $30, and a lifetime estimate of 10 years are from ASAP 2007. We estimate percent applicable as the percent of refrigeration energy use attributed to built-up refrigeration, or 13% (NYSERDA 2003). Stock estimates are from the 2005 TSD (DOE 2005). The levelized cost is calculated to be 0.8 cents/kWh.

Vending Miser

Measure Description: A Vending Miser is an energy control device for refrigerated vending machines. Using an occupancy sensor, the control turns off the machine's lights and duty cycles the compressor based on ambient air temperature.

Basecase: The basecase unit is an efficient vending machine that meets the Energy Star tier II level and uses 2,309 kWh per year (Energy Star calculator for a 600 can machine). Baseline electricity intensity is for the refrigeration end-use (0.88 kWh/ ft^2).

Data Explanation: We assume 35% savings for this measure based on manufacturer data (usatech.com 2008), an incremental cost of $167 (NYSERDA 2003), and a measure life of 10 years (NYSERDA 2003). The levelized cost is calculated to be 2.7 cents/kWh.

Appliances

Efficient Hot Food Holding Cabinets

Measure Description: Commercial hot food holding cabinets are used in the commercial kitchen industry primarily for keeping food at safe serving temperature, without drying it out or further cooking it. These cabinets can also be used to keep plates warm and to transport food for catering events. High efficiency models differ mainly in that they are better insulated.

Basecase: The basecase unit is an uninsulated cabinet that consumes 5,190 kWh per year. This was calculated from CASE (2004) using a simple average of three sizes of cabinets, and then weighting the average using CASE figures for insulated cabinets.

Data Explanation: The energy savings from an insulated holding cabinet are 1,815 kWh per year (35% savings), with an incremental cost of $453, and an estimated 15 year lifetime (ASAP 2007, based on PG&E CASE study (2004)). Percent applicable refers to the 25% of holding cabinets that are currently uninsulated (ASAP 2007, based on PG&E CASE study (2004)). The levelized cost is calculated to be 2.4 cents/kWh.

Efficient Commercial Clothes Washer (excluding hot water energy)

Measure Description: A high-efficiency commercial clothes washer saves both energy and water. For a high-efficiency clothes washer, we assume a unit with an MEF of 2.0, which represent about 80% of products on Energy Star's product lists.

Basecase: The basecase unit is a clothes washer that meets DOE's federal efficiency standard of 1.26 MEF. An average unit consumes 1,530 kWh annually for non-water heating uses, which is derived from DOE 2007.

Data Explanation: Electric savings from this measure assume a 2.0 MEF clothes washer uses an average 1,191 kWh annually, for a 22% savings, which is derived from DOE's TSD (DOE 2007). We assume the measure is applicable to the 39% of units that have electric dryer heating (removal of moisture from clothes), and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Pennsylvania based on commercial building floorspace. We assume an incremental cost for an efficient unit is $316 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 3.7 cents/kWh.

Lighting Measures

Fluorescent Lighting Improvements

Measure Description: The new measure assumes extra-efficient ballasts and high-lumen lamps are installed with no change in light level (low ballast factor).

Basecase: Basecase watts per square foot reflects current installed fixtures. This includes 84,000 annual tube fluorescent kWh used per average 14,000 ft^2 commercial building (Navigant, 2002). On average, fluorescent lights are operated 9.7 hours/day. We assume 2-lamp standard T8 fixtures and electronic ballasts as the baseline, plus a small number of existing 3-lamp T12 fixtures with magnetic ballasts that are not likely to be replaced in the absence of programs over the time horizon.

Data Explanation: We assume a percent savings of 27%.The incremental costs are $2 extra per ballast, and $1 extra for each of 2 lamps. The percent applicable (56%) is the fluorescent percent of total commercial lighting kWh (Navigant 2002). The levelized cost is calculated to be 0.7 cents/kWh.

HID Lighting Improvements

Measure Description: Metal halide lamps produce light by passing an electric arc through a mixture of gases. Efficiency improvements in metal halide lamps include pulse start lamp technology, electronic ballasts, and improved fixtures.

Basecase: Same basecase as #27 (Fluorescent lighting improvements).

Data Explanation: The new measure savings and costs are from a PG&E CASE study on Metal Halide Lamps & Fixtures (PG&E 2004). Energy savings were 447 kWh per year (26%), and incremental costs were $60. Percent applicable (12%) is the percentage of commercial electricity use for lighting that comes from HIDs (Navigant 2002). The levelized cost is calculated to be 6.3 cents/kWh.

Replace Incandescent Lamps with CFLs

Measure Description: The new measure assumes that 70% of current incandescents are replaced with CFLs. These lights represent area and general lighting.

Basecase: The basecase is 2 kWh/sf annually. This represents the amount of energy used for incandescent lighting in the average commercial building, and is derived from the average number of lamps, the average lamp wattage, and the average annual operating time (Navigant 2002).

Data Explanation: Energy savings are 1.5 kWh per sf annually, or 72%. Incremental costs include $10 in the cost of a CFL, but save $32 in labor for replacing the bulb, so the result is a cost savings. ACEEE estimates that 70% of sockets are applicable for the new measure. The levelized cost is calculated to be -1 cent/kWh.

Replace Incandescent Lamps with LEDs

Measure Description: The new measure assumes that 20% of current incandescents (10% low-wattage and 10% miscellaneous) are used for display lighting, and can be replaced with LED lights.

Basecase: The basecase is 0.23 kWh/sf annually. This is derived from the average wattage of quartz halogen, low-wattage, and average incandescents; the average number of each type of bulb in a commercial building; and the average annual operating time (Navigant 2002).

Data Explanation: Energy savings are 0.4 kWh per sf annually, or 88%, assuming LED replacement wattages as indicated by Navigant (2008). Incremental costs include $0.05 per sf, a weighted average of the costs of each bulb, and and including a $32 labor savings for replacing each bulb. The LED prices were calculated using average efficacy and $/klm projections for 2010 (Navigant, LED technical committee, 2008). Percent applicable assumes that 100% of these specific bulbs are replaceable (Navigant 2008). Between this measure and the previous measure (replacing incandescents with CFLs), 90% of incandescents are assumed to be replaceable, allowing 10% of incandescents (for specialty applications) to remain. The levelized cost is calculated to be 3.7 cents/kWh.

Occupancy Sensor for Lighting

Measure Description: Installation of occupancy sensors can greatly reduce lighting energy demands in commercial spaces, by automatically turning off lights in unoccupied spaces.

Basecase: Same basecase as #27 (Fluorescent lighting improvements).

Data Explanation: Energy savings of 361 kWh per year (NYSERDA 2003) assumes 30% energy reduction in individual offices and rooms and 7.5% reduction in open spaces (ACEEE estimate). Incremental cost ($48) and lifetime (10 years) estimates are from NYSERDA 2003. Percent applicable (38%) is from Sachs et al. (2004). The levelized cost is calculated to be 1.7 cents/kWh.

Daylight Dimming System

Measure Description: A daylight dimming system automatically dims electric lights to take advantage (or "harvest") natural daylight.

Basecase: Same basecase as #27 (Fluorescent lighting improvements).

Data Explanation: Energy savings are estimated to be 143 kWh per year, or 35% (NYSERDA 2003). Savings apply for lamps on the perimeters of buildings (25% applicable – PIER 2003). Incremental cost ($68) and lifetime (20 years) estimates are from NYSERDA (2003). The levelized cost is calculated to be 3.8 cents/kWh.

Outdoor Lighting – Controls

Measure Description: This measure includes a variety of lighting control technologies for exterior lights.

Basecase: No basecase data was available for this measure.

Data Explanation: We assume a savings of 174 kWh, or 20%, from lighting controls. Incremental costs of $43 are from DEER 2001 and assume each control on average controls three fixtures. Percent applicable of 30% is an ACEEE estimate. The levelized cost is calculated to be 2.5 cents/kWh.

Miscellaneous

Office Equipment

Measure Description: This measure assumes a high-efficiency fax, printer, computer display, internal power supply, and a low mass copier.

Basecase: Baseline electricity use is 2886 kWh per year (NYSERDA 2003). Baseline electricity intensity for this end-use, 1.8 kWh per ft^2, is the estimated office equipment energy consumption in commercial buildings in Pennsylvania. This is based on the Mid Atlantic region from EIA's commercial buildings survey.

Data Explanation: Energy savings were 1410 kWh per year (49%), lifetime was 5 years, and incremental costs were $20. Percent applicable is estimated to be (50%) (NYSERDA 2003). The levelized cost is calculated to be 0.3 cents/kWh.

Turn off appliances

Measure Description: This measure involves turning off, or putting into a low-power state: vending machines, computers, monitors, printers and copiers.

Basecase: Baseline electricity use is 1.1 kWh/ft2, based on data from CBECS, LBNL, and Energy Star.

Data Explanation: Energy savings were 9114 kWh per year (40%), lifetime was 5 years, and incremental costs were $0. Percent applicable is 100%, as data for the savings already took into account the number of buildings that already shut down equipment after hours/. The levelized cost is $0/kWh

New Buildings

Efficient New Building (15% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: Basecase of 7 kWh per ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Pennsylvania, derived from data for buildings built from 2000-2003 (EIA 2006).

Data Explanation: Incremental cost of $0.35 per ft^2 and measure life of 17 years are from NGRID 2007. The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.16. Percent applicable of 18% for this new buildings measure assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be 1.4 cents/kWh.

Efficient New Building (30% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: Basecase of 7 kWh per ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new VA buildings, derived from data for buildings built from 2000-2003 (EIA 2006).

Data Explanation: In New York, estimates show that commercial buildings can reach 30% beyond code at an investment of $0.54/kWh. To be conservative, we estimate $0.70/kWh by doubling the costs of a 15%-beyond-code building. The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.33. Measure life of 17 years is from NGRID 2007. Percent applicable of 35% for 30% savings new buildings assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be 1.4 cents/kWh.

Tax-Credit Eligible Building (50% Savings)

Measure Description: A federal tax incentive is available for new buildings that are constructed to save at least 50% of the heating, cooling, ventilation, water heating, and interior lighting cost of a building that meets ASHRAE standard 90.1-2001.

Basecase: Basecase of 7 kWh per ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Pennsylvania, derived from data for buildings built from 2000-2003 (EIA 2006).

Data Explanation: Incremental costs of $0.66 per ft2 are derived from NREL (2008) studies on energy savings for medium box retail stores and supermarkets. This cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.35. Percent applicable is 18%, accounting only for the share of buildings that call into the two types of buildings covered in the NREL studies. Measure life of 17 years is from NGRID 2007. The levelized cost is calculated to be 0.8 cents/kWh.

Table B-10. Commercial Building Electricity Measure Characterizations

Measures	Measure Life (Years)	Annual kWh svgs per unit	2007 Penn. Stock	kWh svgs per s.f.	Incremental cost per unit	Incremental cost per s.f.	Cost of Conserved Energy (2006$/kWh saved)	Adjustment Factor	% Turnover	Interaction Factor	Savings in 2025 (GWh)
Existing Buildings											
Building Shell											
Cool roof	20	5,500	NA	0.09	$ 3,750	$ 0.25	$ 0.05	80%	85%	100%	230
Roof insulation	25	NA	NA	0.28	NA	$ 0.07	$ 0.02	35%	100%	100%	380
Low-e windows	25	NA	NA	0.26	NA	$ 0.04	$ 0.01	75%	68%	100%	530
											1,140
HVAC											
Duct testing and sealing	10	24,800	NA	0.53	$ 3,380	NA	$ 0.02	25%	100%	100%	520
Efficient ventilation fans & motors w VFD	10	22,000	NA	0.15	$ 6,650	NA	$ 0.04	40%	100%	84%	200
HVAC Load-Reducing Measures Subtotal											**730**
High-effic. unitary AC & HP (65-135 kbtu)	15	1,100	NA	0.17	$ 630	NA	$ 0.06	33%	100%	82%	180
High-effic. unitary AC & HP (135-240 kbtu)	15	3,400	NA	0.26	$ 1,420	NA	$ 0.04	15%	100%	82%	120
Packaged Terminal HP and AC	15	200	NA	0.19	$ 80	NA	$ 0.04	5%	100%	82%	30
Efficient room air conditioner	13	100	NA	0.16	$ 40	NA	$ 0.04	4%	100%	82%	20
High-efficiency chiller system	23	30,300	NA	0.48	$ 9,900	NA	$ 0.02	33%	74%	82%	370
HVAC Equipment Measures Subtotal											**1,520**
Dual Enthalpy Control	10	3,000	NA	0.26	$ 890	NA	$ 0.04	46%	100%	75%	350
Demand-Controlled Ventilation	15	8,000	NA	0.12	$ 3,450	NA	$ 0.04	54%	100%	75%	190
HVAC tuneup (smaller buildings)	3	900	NA	0.25	$ 160	NA	$ 0.06	22%	100%	75%	160
Energy management system install	10	12,600	NA	0.21	$ 6,380	NA	$ 0.07	33%	100%	75%	200
Retrocommissioning	7	NA	NA	0.24	NA	$ 0.10	$ 0.03	43%	100%	75%	300
HVAC Control Measures Subtotal											**1,090**
HVAC Subtotal											**2,600**
Water Heating											
Commercial clothes washers	11	700	120,000	0.00	$ 320	NA	$ 0.04	14%	100%	100%	10
Heat pump water heater	12	14,200	NA	0.20	$ 4,070	NA	$ 0.03	24%	100%	99%	150
											160
Refrigeration											
Walk-in coolers & freezers	12	8,200		0.38	$ 960	NA	$ 0.01	9%	100%	100%	140
Reach-in coolers & freezers	9	1,300		0.28	$ 180	NA	$ 0.02	15%	100%	100%	170
Ice-makers	10	500		0.14	$ 100	NA	$ 0.02	9%	100%	100%	50
Supermarket (built-up) refrigeration system	10	36,000		0.18	$ 37,000	NA	$ 0.01	33%	100%	100%	240
Vending machines (to tier 2 Energy Star level)	10	500		0.16	$ 30	NA	$ 0.01	13%	100%	100%	80
Vending miser	10	800		0.25	$ 170	NA	$ 0.03	13%	100%	100%	130

											810
Lighting											
Fluorescent lighting improvements	13	100	-	1.24	$ 5	NA	$ 0.01	56%	100%	100%	2,720
HID lighting improvements	2	400	-	1.19	$ 60	NA	$ 0.06	12%	100%	100%	560
Replace incandescent lamps with CFLs	13	200	-	3.16	$ (20)	NA	$ (0.01)	22%	100%	100%	3,970
Replace incandescent lamps with LEDs	9	200	-	0.21	$ 760	$ 0.05	$ 0.04	100%	100%	100%	800
Occupancy sensor for lighting	10	400	-	0.85	$ 60	NA	$ 0.02	38%	100%	70%	820
Daylight dimming system	20	100	-	1.59	$ 70	NA	$ 0.04	25%	85%	65%	790
											8,210
Office Equipment											
Office equipment	5	1,400	-	0.87	$ 0.01	$ 20	$ 0.003	50%	100%	100%	1,690
Turn off office equipment after-hours	5	9,100	NA	0.44	$ -	$ -	$ -	100%	100%	81%	1,400
											3,090
Appliances/Other											
Hot Food Holding Cabinets	15	1,800	14,700	NA	$ 453	NA	$ 0.02	25%	100%	100%	10
Commercial clothes washers - 2.0 MEF	11	300	120,000	NA	$ 316	NA	$ 0.04	31%	100%	100%	10
											20
Existing Buildings Subtotal											**16,350**
New Buildings											
Efficient new building (15% savings)	17	NA	-	1.04	NA	$ 0.16	$ 0.03	18%	100%	100%	110
Efficient new building (30% savings)	17	NA	-	2.09	NA	$ 0.33	$ 0.03	35%	100%	100%	440
Tax credit eligible building (50% svgs)	17	NA	-	3.48	NA	$ 0.31	$ 0.08	18%	100%	100%	370
											920
										TOTAL	**17,260**

Natural Gas Analysis

Baseline End-Use Natural Gas Consumption

To estimate the resource potential for efficiency in commercial buildings in Pennsylvania, we first develop a disaggregate characterization of baseline natural gas consumption in the state for current gas use and a reference load forecast (see Table B-11 below). Highly disaggregated commercial gas consumption data is unfortunately not available at the state level. To estimate these data, we start with current natural gas consumption for the Pennsylvania commercial sector (EIA 2008) and a forecast out to 2025 based on PJM forecasts, and we disaggregate by end-use using average regional data from CBECS 2003 (EIA 2006) and AEO 2007 (EIA 2007).

Table B-11. Baseline Commercial Natural Gas Consumption by End-Use (MMBtu)

End-Use	2009	%	2015	%	2025	%
Heating	72,500,000	48%	79,600,000	48%	82,300,000	47%
Cooling	4,700,000	0%	5,200,000	0%	4,900,000	0%
HVAC subtotal	*73,000,000*	*49%*	*80,200,000*	*49%*	*82,800,000*	*47%*
Water Heating	30,100,000	20%	33,100,000	20%	36,600,000	21%
Cooking	13,500,000	9%	14,800,000	9%	16,500,000	9%
Other	32,700,000	22%	36,000,000	22%	38,200,000	22%
Total	149,600,000	100%	164,300,000	100%	174,400,000	100%

Next, we estimate commercial square footage in the state using natural gas intensity data (MBtu per square foot) by census region from CBECS (EIA 2006). We use the Mid Atlantic census region to estimate an overall natural gas intensity for the state of Pennsylvania of 45 MBtu per square foot. Total natural gas consumption in the state divided by the natural gas intensity provides an estimate of commercial floorspace. Using this methodology, we estimate 3,910 million square feet of commercial floorspace in the state.

Measure Cost-Effectiveness

We then analyze 24 efficiency measures for existing commercial buildings and 2 new construction whole-building measures to examine the cost-effective energy efficiency resource potential. For each efficiency measure, we estimate natural gas savings (*Annual Savings per Measure)* and incremental cost (*Measure Cost)* in a "replacement on burnout scenario," which assumes that the product is replaced or the measure is installed at the end of the measure's useful life. Savings and costs are incremental to an assumed *Baseline Measure*. We estimate savings (MMBtu) and costs ($) on a per-unit and/or a per-square foot commercial floorspace basis. For each measure we also assume a *Measure Lifetime*, or the estimated useful life of the product.

A measure is determined to be cost-effective if its levelized cost of saved energy, or cost of conserved energy (CCE), is less than $12.45/MMBtu, the estimated current average commercial cost of natural gas in Pennsylvania. The estimated CCE for each efficiency measure, which assume a discount rate of 5%, are shown in the measure descriptions below. Equation 1 shows the calculation for cost of conserved energy.

Our assumed *Baseline Measure*, *Annual Savings per Measure, Measure Cost, Measure Lifetime, and CCE* are reported for each of the efficiency measures in the list of measure descriptions below. We group the 24 efficiency measures for existing commercial buildings by end-use and list the 2 new building measures last.

Equation 1. CCE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure (kWh))

Total Statewide Resource Potential

For each measure, we then derive *Annual Savings per Measure* on a per square foot basis *(MBtu per square foot)* for the applicable end-use*.* For measures that we only have savings on a per-unit or per-building basis, we first derive the percent savings and multiply by the *Baseline Natural Gas Intensity* for that end-use. The assumed baseline intensities for each end use are shown in Table B-12. As an example, for a specific HVAC measure we multiply its percent savings by the baseline gas intensity (MBtu per square foot) for the HVAC end-use.

Table B-12. Commercial End-Use Baseline Natural Gas Intensities (MBtu per s.f.)

End Use	2009
Heating	21.9
Cooling	0.1
Ventilation	0.0
Water Heating	9.1
Cooking	4.1
Other	9.9
HVAC Subtotal	22.0
Total	45.2

To estimate the total efficiency resource potential in existing commercial buildings in Pennsylvania by 2025, we must first adjust the individual measure savings by an *Adjustment Factor* (See Equation 2). This factor accounts for two adjustments: the technical feasibility of efficiency measures, called the *Percent Applicable* (the percent of Pennsylvania floorspace that satisfy the base case conditions and other technical prerequisites such as heating fuel type and cooling equipment, etc); and the *Current Market Share*, or the percent of products that already meet the efficiency criteria. These assumptions are outlined in each of the efficiency measure descriptions below.

Equation 2. Adjustment Factor = Percent Applicable x (1-Current Market Share).

We then adjust total savings for interactions among individual measures. For example, we must adjust HVAC equipment savings downward to account for savings already realized through improved building envelope measures (insulation and windows), which reduce heating and cooling loads. Similarly, we adjust water heating equipment savings to account for reduced water heating loads from the use of more efficient clothes washers. The multiplier for these adjustments is called the *Interaction Factor.*

Finally, we adjust replacement measures with lifetimes more than 7 and 17 years to only account for the percent turning over in 7 and 17 years, which represents the benchmark years of 2015 and 2025, respectively. Note that the multiplier, *Percent Turnover,* is only applicable to products being replaced upon burnout and not retrofit measures such as insulation. These retrofit measures therefore have 100% of measures “turning over.”

We then calculate the resource potential for each measure in the state using Equation 3, which takes into account all of the adjustments described above. The sum of the resource potential from all measures is the overall energy efficiency resource potential in the state’s commercial buildings sector.

Equation 3. Efficiency Resource Potential in 2015 and 2025 (MMBtu) = (Annual Savings per Measure (MMBtu) per square foot)) x (Commercial floor space in Pennsylvania in millions of square feet) x (Percent Applicable) x (Interaction Factor) x (Percent Turnover)

Efficiency Measures

Table B-13 shows the thirty-eight efficiency measures examined for this analysis, grouped by end-use costs, savings (MBtu) per product or square foot, *Percent Applicable, Interaction Factor, Percent Turnover,* and total savings potential (MMBtu) in 2025. Detailed descriptions of each measure are given below, grouped by end-use.

Building Shell Improvements

Roof insulation

Measure Description: Fiberglass or cellulose insulation material in roof cavities will reduce heat transfer, though the type of building construction limits insulation possibilities. R-values describe the performance factor for insulation levels.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percentage of savings.

Data Explanation: We assume 3% savings and a post-savings gas intensity 21.3 Mbtu/ft^2/year, based on an average of four building types (ACEEE 1997). An average lifetime of 25 years (CL&P 2007) and an incremental cost of 12 cents/ft^2 were also assumed. The measure is shared with gas savings as well, so the portion of the incremental cost attributed to gas savings is 5 cents/sf. The levelized cost is $5.13/MMBtu.

Double Pane Low-Emissivity Windows

Measure Description: Double-pane windows have insulating air- or gas-filled spaces between each pane, which resist heat flow. Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer back through the window, and a window's R-value represents the amount of heat transfer back through a window. Low-e windows are particularly useful in climates with heavy cooling loads, because they can reflect anywhere from 40% to 70% of the heat that is normally transmitted through clear glass. The Solar Heat Gain Coefficient (SHGC) represents the fraction of solar energy transferred through a window. For example, a low-e window with a 0.4 SHGC keeps out 60% of the sun's heat.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percent savings.

Data Explanation: Percent savings of 3% apply to whole-building electricity consumption (ACEEE 1997). Incremental costs assume $2 per window (SWEEP 2002). This measure is shared with gas savings as well. A measure life of 25 years is from SWEEP 2002. Percent applicable is an ACEEE estimate. The levelized cost is calculated to be $3.40/MMBtu.

Heating and Cooling: Equipment and Controls

Boiler tune-up

Measure Description: A boiler tune-up should be done regularly to keep the boiler system running at optimal efficiency.

Basecase: Same basecase as for high-efficiency main/front-end boilers is assumed (#4).

Data Explanation: A boiler tune-up saves 2% of the energy of a baseline unit annually, or 30 MMBtu, and has an incremental cost of $250 per boiler (GDS 2005). Percent applicable of 7% was calculated using CBECS data of percentage of buildings with boilers that don't perform regular maintenance (CBECS 2003). We assume a measure life of 2 years (GDS 2005). The levelized cost is $1.80/MMBtu.

Duct sealing

Measure Description: Duct sealing involves sealing gaps in ductwork that allow conditioned air to escape.

Basecase: The basecase is standard heating and cooling energy intensity, 22 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 18% (84 MMBtu) of heating and cooling energy annually, and has an incremental cost of $7,000 (Sachs et al 2004). Percent applicable is 23% based on the number of buildings under 25,000 sf, and the measure life is 25 years (Sachs et al 2004). The levelized cost is $0.59/MMBtu.

Pipe insulation

Measure Description: This measure includes insulating accessible steam or hot water supply pipes in the boiler room.

Basecase: The basecase is standard heating energy intensity, 21.9 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (9 MMBtu) of heating energy annually (NYSERDA 2006), and has an incremental cost of $450, based on an ACEEE estimate of 75 feet of pipe to insulate at $6 per linear foot of pipe (RSMeans). Percent applicable is 48%, current market share is 75%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $4.78/MMBtu.

High-efficiency rooftop furnace unit

Measure Description: This measure involves technologies such as condensing units to capture latent heat from water vapor in the flue, and modulating units which have a variable firing rate to match the output to heat load.

Basecase: The basecase is a 10 ton gas-fired condensing rooftop packaged unit with 80% steady state efficiency. The average annual gas use is 179 MMBtu (Sachs et al. 2004).

Data Explanation: A high efficiency rooftop unit uses 150 MMBtu/year, saves 16% of basecase energy, and has an incremental cost of $1,000 (Sachs et al. 2004). Percent applicable is 35% based on the percent of buildings less than 100,000 square feet multiplied by the assumption that the following percentages of size buildings use rooftop units: 40% of buildings 1,000-5,000 sf, 80% of buildings 5,000-25,000 sf, and 66% of buildings 25,000-100,000 sf. This assumption is based on CBECS data as well as ACEEE estimates. We assume a measure life of 15 years and 0% current market share (Sachs et al. 2004). The levelized cost is shown to be $3.42/MMBtu.

High-efficiency standalone furnace

Measure Description: This measure replaces minimum-efficiency gas furnaces with condensing furnaces and/or modulating capacity (variable firing rate that matches the output to heat load).

Basecase: The basecase is a 80 AFUE residential furnace. The average annual gas use is 142 MMBtu (Energy Star figure modified by a factor of 1.45 to represent the slightly larger average size of a small commercial building than a residential building).

Data Explanation: A high efficiency furnace with 90 AFUE (Energy Star minimum) uses 126 MMBtu/year, saves 11% of basecase energy, and has an incremental cost of $464 (Energy Star; cost and savings modified as per basecase). Percent applicable is 2% based on the percent of buildings less than 5,000 square feet multiplied by the assumption that 40% of smaller buildings use furnaces. This assumption is based on CBECS data as well as ACEEE estimates. We assume a measure life of 18 years and 35% current market share (Energy Star). The levelized cost is shown to be $2.51/MMBtu.

High-efficiency boiler

Measure Description: Substitution of condensing boilers with outdoor reset or equivalent controls (including circulation pump time clocks) for basecase non-condensing boilers without adaptive controls (just thermostats and equivalent).

Basecase: A case study of boilers with 68% efficiency was assumed. The average annual gas use is 1,491 MMBtu, which was modified from the original statistic (26,267 MMBtu) to account for the difference in the case study building size and the average commercial building size in Pennsylvania (Sachs et al. 2004).

Data Explanation: Boilers with 90% efficiency use 1,121 MMBtu/year in an average commercial building, save 50% of basecase energy (Durkin), and have an incremental cost of $3,267 (Sachs et al. 2004). The cost reflects the incremental cost of a high-efficiency boiler as well as the cost of an outdoor temperature reset system. Percent applicable is 41% based on assumptions of percentage of buildings in each size class that use boilers and an assumption of 90% that can be easily replaced, per CBECS and ACEEE estimates. We assume a measure life of 24 years (Sachs et al. 2004). The levelized cost is shown to be $0.76/MMBtu.

Programmable thermostat
Measure Description: This measure involves replacing conventional thermostats with programmable thermostats. This measure is only appropriate to smaller buildings.

Basecase: The basecase of 49 MBtu/ft2 is the standard heating and cooling intensity modified by the overall intensity ratio of small buildings to the average (EIA 2006 and 2007).

Data Explanation: This measure saves 5% (12 MMBtu) of heating energy annually (RLW 2007). The measure has an incremental cost of $101 (CEC 2005) and a percent applicable of 8%. The percent applicable derives from the percentage of Mid-Atlantic commercial buildings under 2,000 s.f. and the fact that 47% of these buildings do not do setback or have an EMS (EIA 2006). The measure life is 12 years (GDS 2005) and the levelized cost is $0.97/MMBtu.

EMS
Measure Description: An Energy Management System (EMS) is a control system for larger buildings that provides for zone-specific automated heating/cooling control.

Basecase: The basecase is standard heating energy intensity, 21.9 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 7% (30 MMBtu) of heating energy annually and has an incremental cost of $495 (CEC 2005). The percent applicable of 30% is based on the percentage of Mid-Atlantic commercial buildings over 2,000 sf and the percentage of these buildings that do not do setback or have an EMS (EIA 2006). The measure life is 14 years (CEC 2005) and the levelized cost is $1.67/MMBtu.

Demand-controlled ventilation
Measure Description: Often, HVAC systems are designed to supply ventilated air based on assumed occupancy levels, resulting in over-ventilation. Demand-controlled ventilation monitors CO_2 levels in different zones and delivers the required ventilation only when and where it is needed.

Basecase: The basecase energy use is 215 MMBtu/year, or the portion of commercial gas heating attributable to ventilation (Sachs et al 2004).

Data Explanation: Demand-controlled ventilation saves 20% of the ventilation energy a year (43 MMBtu), and has an incremental cost of $575 per zone (six zones were assumed as an average, for a total cost of $3,450) (Sachs et al 2004). Percent applicable is 54%, and the measure life is 15 years (Sachs et al 2004). The levelized cost is $7.75/MMBtu.

Outdoor temperature boiler reset
Measure Description: Normally, boilers heat water to a fixed temperature. With an outdoor air reset system, the maximum temperature the boiler operates at is variable, depending on the outdoor temperature. The warmer the outdoor temperature, the lower the boiler temperature needs to be, saving energy over the standard fixed (high) temperature operation of a conventional boiler.

Basecase: The basecase is standard heating energy intensity, 21.9 MBtu/ft2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (9 MMBtu) of heating energy annually (NYSERDA 2006), and has an incremental cost of $600 (GDS 2005). Percent applicable is 5%, based on the percent of boilers not included in the High Efficiency Boiler measure. The current market share is 62% (NYSERDA 2006), and the measure life is 15 years (ACEEE 2006). The levelized cost is $6.38/MMBtu.

Water Heating

Tank insulation
Measure Description: Commercial water heater insulation is available either by the blanket or by square foot of fiberglass insulation with protective facing.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (4 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $11.95 per square foot (RSMeans) with an assumed 180 square feet of tank surface area. Percent applicable is 50%, current market share is 53%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $11.91/MMBtu.

Pipe insulation
Measure Description: This measure includes insulating accessible DHW supply pipes.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (4 MMBtu) of heating energy annually (NYSERDA 2006), and has an incremental cost of $450, based on an ACEEE estimate of 75 feet of pipe to insulate at $6 per linear foot of pipe (RSMeans). Percent applicable is 50%, current market share is 56%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $11.50/MMBtu.

Smart circulation pump controls
Measure Description: This measure involves shutting down the DHW recirculation pump during periods when there is little or no demand for hot water. These periods are determined by the controls from historical use patterns. This leads to savings from heat loss through piping, as well as savings associated with the running of the pump.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 3% (6 MMBtu) of water heating energy annually, and has an incremental cost of $143 (GDS 2005). Percent applicable is 5% based on the percent of buildings with boilers that are not covered in the high efficiency boiler measure, and the measure life is 15 years (GDS 2005). The levelized cost is $2.44/MMBtu.

Condensing DHW stand-alone tank
Measure Description: This measure involves a new high-efficiency residential-sized tank-type gas water heater, for smaller commercial operations.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 36% (68 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $1,100 (Sachs et al. 2004). Percent applicable is 35%, current market share is 5%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $1.56/MMBtu.

Indirect-fired DHW off space heating boiler
Measure Description: DHW cylinders are heated indirectly with water from the boiler.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 30% (56 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $4,000. Percent applicable is 7%, the current market share is close to 0%, and the measure life is 25 years (NYSERDA 2006). The levelized cost is $5.10/MMBtu.

Instantaneous high-modulating water heater
Measure Description: "Instant" or "tankless" water heaters heat water on demand. Advanced units have modulating burners with electronic controls to maintain constant outlet temperature despite variations in inlet temperature and variable demand.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 21% (39 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $650 (Sachs et al. 2004). Percent applicable is 4%, the current market share is 18%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $1.62/MMBtu.

Cooking

Direct fired convection range/oven

Measure Description: Convection ovens use a small fan to circulate hot air within the oven cavity. Circulating air can heat food more efficiently than the still air found in conventional ovens.

Basecase: A conventional range/oven uses approximately 160 MMBtu/year (Food Service Technology Center 2002).

Data Explanation: This measure saves 35% (56 MMBtu) per year per unit (GDS 2005), and has an incremental cost of $2,625 (RSMeans 2008). The measure life is 8 years and the percent applicable is 5%, which accounts for weighted applicability in only the commercial sectors that would have ovens (NYSERDA 2006). The levelized cost is $7.25/MMBtu.

High efficiency Energy Star fryer

Measure Description: Energy Star fryers can save 15-25% of the energy used by a conventional model. High-efficiency gas fryers utilize technology such as heat pipes, infrared burners, recirculation tubes, power burners, and pulse combustion.

Basecase: A conventional fryer uses 163 MMBtu per year on average (EPA 1007).

Data Explanation: An Energy Star fryer saves 31% (51 MMBtu) per year per unit, and has an incremental cost of $3,795 (Energy Star). Current market share is 11% (EPA 2007), and the stock data (341,570 units) was derived from national annual shipments (EPA 2007), measure life (12 years – Energy Star), and the ratio of commercial buildings that include cooking equipment that use natural gas (CBECS).The levelized cost is $8.48/MMBtu.

High efficiency Energy Star steam cooker

Measure Description: Energy Star steam cookers have better insulation to reduce heat loss, and a more efficient steam delivery system. These steamers can be up to 50% more energy-efficient than conventional steamers.

Basecase: A conventional steamer uses 91 MMBtu per year on average (data derived from Energy Star and Food Service Technology Center data).

Data Explanation: An Energy Star steam cooker saves 50% (45 MMBtu) per year per unit (Energy Star), and has an incremental cost of -$1,995 (CEC 2005). Current market share is 8%, and the stock data (576,226 units) was derived from national annual shipments (Energy Star), measure life (10 years – Food Service Technology Center 2002), and the ratio of commercial buildings that include cooking equipment that use natural gas (EIA 2006). The levelized cost is -$5.63/MMBtu.

High efficiency griddle

Measure Description: High efficiency griddles take advantage of technologies such as double sided griddles, chrome finishes, snap-action thermostats, infrared burners, heat pipes, thermal fluid or steam to reduce energy consumption.

Basecase: A conventional griddle uses 112 MMBtu per year on average (Food Service Technology Center 2002).

Data Explanation: A high efficiency griddle saves 30% (34 MMBtu) of energy per year per unit (GDS 2005), and has an incremental cost of $1,999 (CEC 2005). Percent applicable is 90%. The levelized cost is $6.72/MMBtu.

Miscellaneous

Retrocommissioning

Measure Description: Retrocommissioning results in optimized energy usage of buildings through better operations and maintenance, control calibration, and facilities staff training.

Basecase: The basecase is average heating, cooling, and water heating energy intensity, 31.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 10% (64 MMBtu) of heating, cooling, and water heating energy (Sachs et al 2004), and has an incremental cost of $0.25 per square foot. This cost is shared with electric savings from the same measure, so the actual cost of gas savings is $0.15. Percent applicable is 54%, and the measure life is 7 years (Sachs et al 2004). The levelized cost is $8.20/MMBtu.

Refrigeration heat recovery
Measure Description: This measure involves waste heat recovery from refrigeration systems for end-users with large refrigeration loads.

Basecase: The basecase is standard water heating energy intensity, 9.1 MBtu/ft^2. This is the average of data for the Mid-Atlantic region (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 14% (26 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $3,000. Percent applicable is 12%, current market share is 4%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $10.94/MMBtu.

New Buildings

Efficient new building (15% savings)
Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: The basecase is 26.6 MBtu/ft2 per year, based on the HVAC and water heating energy intensities for commercial buildings built between 2000 and 2003 (EIA 2006).

Data Explanation: Incremental cost of $0.35 per ft2 and measure life of 17 years are from NGRID 2007. The cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.19. Percent applicable of 18% for this new buildings measure assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be $4.11/MMBtu.

Efficient new building (30% savings)
Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: The basecase is 26.6 MBtu/ft2 per year, based on the HVAC and water heating energy intensities for commercial buildings built between 2000 and 2003 (EIA 2006).

Data Explanation: In New York, estimates show that commercial buildings can reach 30% beyond code at an investment of $0.54/kWh. To be conservative, we estimate $0.70/kWh by doubling the costs of a 15%-beyond-code building. The cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.37. Measure life of 17 years is from NGRID 2007. Percent applicable of 35% for 30% savings new buildings assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be $4.11/MMBtu.

Tax-Credit Eligible Building (50% Savings)
Measure Description: A federal tax incentive is available for new buildings that are constructed to save at least 50% of the heating, cooling, ventilation, water heating, and interior lighting cost of a building that meets ASHRAE standard 90.1-2001.

Basecase: Basecase of 26.6 Mbtu per ft2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Pennsylvania, derived from data for buildings built from 2000-2003 (EIA 2006).

Data Explanation: Incremental costs of $0.66 per ft2 are derived from NREL (2008) studies on energy savings for medium box retail stores and supermarkets. This cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.35. Percent applicable is 18%, accounting only for the share of buildings that call into the two types of buildings covered in the NREL studies. Measure life of 17 years is from NGRID 2007. The levelized cost is calculated to be $2.32/MMBtu.

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Table B-13. Commercial Natural Gas Measure Characterizations

Measures	Measure Life (Years)	Annual MMBtu svgs per unit	2007 Virginia Stock	MBtu svgs per s.f.	Incremental cost per unit	Incremental cost per s.f.	Cost of Conserved Energy (2006$/MMBtu saved)	Adjustment Factor	% Turnover	Interaction Factor	Savings in 2025 (GWh)
Existing Buildings											
HVAC											
Boiler tune-up	2	30	NA	1.44	$ 250	$ -	$ 4.51	7%	100%	100%	394,000
Duct sealing	25	84	NA	4.06	$ 7,000	$ 0.34	$ 5.90	23%	68%	100%	2,485,000
Pipe insulation - heating	15	9	NA	0.44	$ 600	$ -	$ 6.38	12%	100%	100%	205,000
Load-Reducing Measures Subtotal											**3,084,000**
High Efficiency rooftop furnace unit	15	28	NA	1.36	$ 1,000	$ -	$ 3.42	35%	100%	96%	1,786,000
High efficiency standalone furnace	18	16	NA	0.76	$ 464	$ -	$ 2.51	1%	94%	96%	35,000
High efficiency main/front-end boiler	24	369	NA	17.83	$ 3,870	$ -	$ 0.76	37%	71%	96%	17,650,000
HVAC Equipment Measures Subtotal											**19,470,000**
Programmable thermostat	12	4	NA	2.45	$ 100	$ -	$ 3.10	8%	100%	70%	568,000
Demand-controlled ventilation	15	43	NA	2.07	$ 3,450	$ -	$ 7.75	54%	100%	70%	3,060,000
Outdoor temperature boiler reset	15	9	NA	0.44	$ 600	$ -	$ 6.38	2%	100%	70%	21,000
HVAC Control Measures Subtotal											**3,650,000**
HVAC Subtotal											**26,200,000**
Water Heating											
Tank insulation	15	4		0.18	$ 460	$ -	$ 11.91	24%	100%	100%	168,000
Pipe insulation - water heating	15	4		0.18	$ 400	$ -	$ 10.22	22%	100%	100%	155,000
Load-Reducing Measures Subtotal											**323,000**
Circulation pump time clock	15	6		0.27	$ 140	$ 0.01	$ 2.44	5%	100%	98%	48,000
Control Measures Subtotal											**48,000**
Condensing DHW stand-alone tank	15	68	NA	3.28	$ 1,100	$ -	$ 1.56	33%	100%	98%	4,120,000

Indirect-fired DHW off space heating boiler	25	56		2.68	$ 4,000	$ -	$ 5.10	7%	68%	98%	467,000
Tankless high-modulating water heater	15	39		1.87	$ 650	$ -	$ 1.62	4%	100%	98%	253,000
Equipment Measures Subtotal											**4,840,000**
Energy Star washer	11	3	120,000	0.00	$ 500	$ -	$ 21.28	40%	100%	83%	113,000
Peripheral Measures Subtotal											**113,000**
Water Heating Subtotal											**5,393,000**
Cooking											
Direct fired convection range/oven	8	56		2.70	$ 2,630	$ -	$ 7.25	5%	100%	100%	576,000
High efficiency Energy Star fryer	12	51	342,000	0.00	$ 3,800	$ -	$ 8.48	11%	100%	100%	1,897,000
High efficiency Energy Star steam cooker	10	45	576,000	0.00	$ (1,960)	$ -	$ (5.63)	8%	100%	100%	2,074,000
High efficiency griddle	12	15		0.74	$ 50	$ -	$ 0.37	90%	100%	100%	2,616,000
											7,164,000
Miscellaneous											
Retrocommissioning	7	64	NA	3.11	$ -	$ 0.15	$ 8.20	54%	100%	100%	6,572,000
Refrigeration heat recovery	15	26	NA	1.28	$ 3,000	$ -	$ 10.94	12%	100%	100%	588,000
											7,160,000
Existing Buildings Subtotal											**42,730,000**
New Buildings											
Efficient new building (15% savings)	17	NA	NA	4.00	NA	$ 0.19	$ 4.11	18%	100%	100%	418,000
Efficient new building (30% savings)	17	NA	NA	7.99	NA	$ 0.37	$ 4.11	35%	100%	100%	1,673,000
Tax credit eligible building (50% svgs)	17	NA	NA	13.32	NA	$ 0.35	$ 2.32	18%	100%	100%	1,422,000
											3,513,000
										TOTAL	**44,820,000**

Table B-14. Commercial Propane Measure Characterizations

Measures	End-Use Category	Annual savings per household (gallons)	Cost of Saved Energy ($/gallon)	Pass Cost-Effective Test?	% Turnover	Adjustment Factor	Interaction Factor	% End Use Savings	Total Savings in 2025 (Mgal)
Commercial Oil Hot Water Space Heat									
Boiler tuneup	Load (Hot Water)	$88.19	$0.65	yes	100%	50%	100%	2%	4.8
Modulate water temp.	Load (Hot Water)	$189.16	$0.31	yes	47%	25%	100%	1%	2.6
Setback controls	Load (Hot Water)	$117.07	$0.55	yes	70%	50%	100%	3%	6.7
Roof insulation	Load (Hot Water)	$129.11	$0.99	yes	35%	37%	100%	2%	3.6
New windows	Load (Hot Water)	$166.00	$0.94	yes	23%	60%	100%	3%	8.3
Space Heating Load Reducing Measures								11%	26.1
Replace heating system	Equipment (Hot Water)	$244.41	$1.44	yes	23%	60%	100%	5%	13.1
Total Oil Steam Space Heat								16%	39.2
Commercial Water Heating									
Pipe insulation	Water Heating	$33.60	$0.86	yes	47%	50%	100%	1%	3.1
Pump controller	Water Heating	$102.13	$1.32	yes	47%	60%	100%	6%	14.1
New boiler	Water Heating	$42.98	$0.15	yes	23%	67%	100%	2%	5.2
New water heater	Water Heating	$23.48	$1.44	yes	70%	33%	100%	1%	1.2
Total Water Heating Savings								10%	23.6

Industrial Sector

Overview of Approach

According to *Manufacturing Energy Consumption Survey (MECS)* (EIA 2005), the northeastern region (which includes Pennsylvania) industrial energy use is broken down as follows: electricity (22%), natural gas (35%), oil (6%), coal & coke (8%), and other (29%). Therefore, this analysis focused on the electricity and natural gas savings potential. It was accomplished in several steps. First, the industrial market in Pennsylvania was characterized at a disaggregated level and energy consumption for key end-uses was estimated. Then cost effective energy-saving measures were selected based on the projected average retail industrial electricity and natural gas prices. The economic potential savings for these measures was estimated by applying the efficiency measures to end-use energy consumption. The following sections described the process for estimating the savings potential in Pennsylvania.

Market Characterization and Estimation of Base Year Electricity Consumption

The industrial sector is made up of a diverse group of economic entities spanning agriculture, mining, construction and manufacturing. Significant diversity exists within most of these industry sub-sectors, with the greatest diversity within manufacturing. The various product categories within manufacturing are classified using the North American Industrial Classification System (NAICS) (Census 2002).[7]

Comprehensive, highly-disaggregated electricity or natural gas data for the industrial sector is not available at the state level. To estimate the electricity and natural gas consumption, this study drew upon a number of resources, all using the NAICS system and a consistent sample methodology. Fortunately, a conjunction of the various economic censuses for each state allows us to use a common base-year of 2002.

We then used national industry energy intensities derived from industry group electricity and natural gas consumption data reported in the *2005 Annual Energy Outlook* (AEO) (EIA 2005) and value of shipments data reported in the *2002 Annual Survey of Manufacturing* (ASM) (Census 2005) to apportion industrial energy consumption. These intensities were then applied to the value of shipments data for the manufacturing energy groups (three-digit NAICS) in Pennsylvania. These energy consumption estimates were then used to estimate the share of the industrial sector electricity and natural gas consumption for each sub-sector.

Preparation of Baseline Industrial Electricity Forecast

As is the case for state-level energy consumption data, no state-by-state disaggregated electricity or natural gas consumption forecasts are publicly available. Several alternate data sources were used to calculate estimated energy consumption growth rates for each state and sub-sector. We made the assumption that energy consumption will be a function of gross state value of shipments (VOS). Electricity and natural gas consumption, however, will not grow at the same rate as value of shipments. This is because in general, energy intensity (energy consumed per value of output) decreases with time.

Because state-level disaggregated economic growth projections are not publicly available, data was used from Moody's Economy.com. The average growth rate for specific industrial-subsectors was estimated based on Economy.com's estimates of gross state product. We used this estimated industrial energy consumption distribution to apportion the EIA estimate (2005) of industrial energy consumption.

The industry sector is comprised of four sub-sectors: Manufacturing, Mining, Agriculture, and Construction. The manufacturing sector is broken down into 21 subsectors, defined by three digit

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[7] The industry sector is comprised of four sub-sectors: Manufacturing, Mining, Agriculture, and Construction. Each sub-sector is further broken down into individual industry groups reflecting the many different definitions for the term 'industrial.'

NAICS codes. In order to most closely match available data from the *ASM* and *AEO*, three subsectors were further broken down to four digit NAICS codes: chemical manufacturing, nonmetallic mineral product manufacturing, and primary metal manufacturing. Table B-15 below shows the estimated electrical and natural gas consumption for all these subsectors in Pennsylvania in 2008.

Table B-15. 2008 Electricity and Natural Gas Consumption by Industry in Pennsylvania

Industry	**NAICS Code**	**Electricity**		**Natural Gas**	
		(GWh)	(%)	(BBtu)	(%)
Agriculture	**11**	797	2%	1,756	1%
Mining	**21**	987	2%	5,793	3%
Construction	**23**	1,392	3%	5,839	3%
Food mfg	311	2,057	4%	8,911	5%
Beverage & tobacco product mfg	312	333	1%	709	0%
Textile mills	313	211	0%	451	0%
Textile product mills	314	181	0%	387	0%
Apparel mfg	315	587	1%	1,251	1%
Leather & allied product mfg	316	59	0%	125	0%
Wood product mfg	321	638	1%	1,431	1%
Paper mfg	322	2,686	5%	9,977	5%
Printing & related support activities	323	915	2%	1,950	1%
Petroleum & coal products mfg	324	1,630	3%	17,129	9%
Chemical mfg	325	12,987	26%	74,749	40%
Pharmaceutical & medicine mfg	*3254*	*9,340*	*19%*	*53,757*	*29%*
All other chemical products	*-3253,3255-*	*3,647*	*7%*	*20,992*	*11%*
Plastics & rubber products mfg	326	1,170	2%	2,757	1%
Nonmetallic mineral product mfg	327	4,409	9%	9,854	5%
Glass & glass product mfg	*3272*	*1,030*	*2%*	*6,120*	*3%*
Cement & concrete product mfg	*3273*	*3,092*	*6%*	*3,122*	*2%*
Other minerals	*3271,3274-*	*287*	*1%*	*611*	*0%*
Primary metal mfg	331	12,392	25%	31,768	17%
Iron & steel mills & ferroalloy mfg	*3311*	*3,894*	*8%*	*16,128*	*9%*
Steel product mfg from purchased steel	*3312*	*1,036*	*2%*	*4,293*	*2%*
Alumina and Aluminum	*3313*	*2,359*	*5%*	*2,929*	*2%*
Nonferrous Metals, except Aluminum	*3314*	*4,384*	*9%*	*5,441*	*3%*
Foundries	*3315*	*719*	*1%*	*2,978*	*2%*
Fabricated metal product mfg	332	1,237	2%	1,966	1%
Machinery mfg	333	886	2%	1,404	1%
Computer & electronic product mfg	334	785	2%	1,274	1%
Electrical equipment, appliance, & component mfg	335	476	1%	767	0%
Transportation equipment mfg	336	862	2%	1,389	1%
Furniture & related product mfg	337	639	1%	1,362	1%
Miscellaneous mfg	339	1,246	3%	2,656	1%
Total Industrial Sector		49,561	100%	185,656	100%

Market Characterization Results

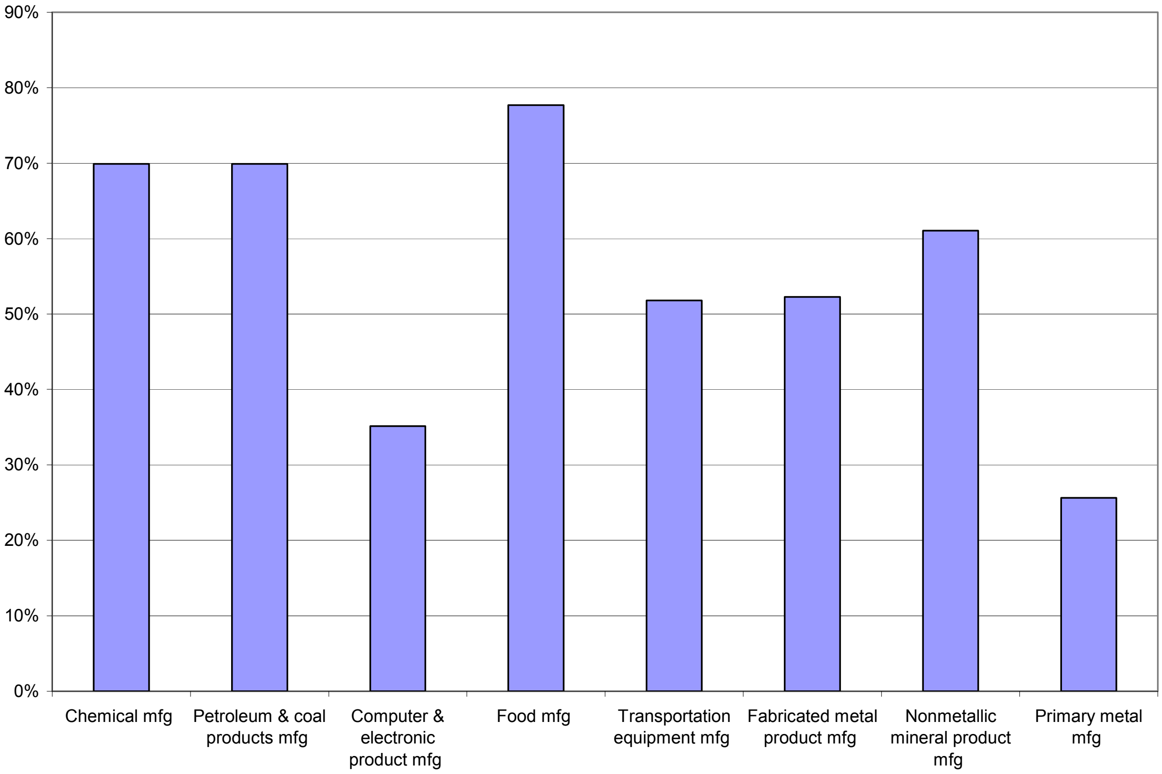
In 2008, the State of Pennsylvania industrial sector consumed 49,561 GWh of electricity and 185,656 billion Btus of natural gas. Within the manufacturing sector, the chemical, primary metal, and non-metallic mineral manufacturing industries are the largest consumers of energy, accounting for over 60% of both electricity and natural gas.

Industrial Electricity End Uses

In order to determine the electricity savings for any technology, the fraction of the electricity to which the technology is applicable must be determined. Much of the energy consumed by industry is directly involved in processes required to produce various products. Electricity accounts for about a third of the primary energy used by industries (EIA 2005). Electricity is used for many purposes, the most important being to run motors, provide lighting, provide heating, and to drive electrochemical processes.

While detailed end-use data is only available for each manufacturing sub-sector and group through the MECS survey (EIA 2005), motor systems are estimated to consume 60% of the industrial electricity (Xenergy 1998). The fraction of total electricity attributed to motors is presented in Figure B-1.

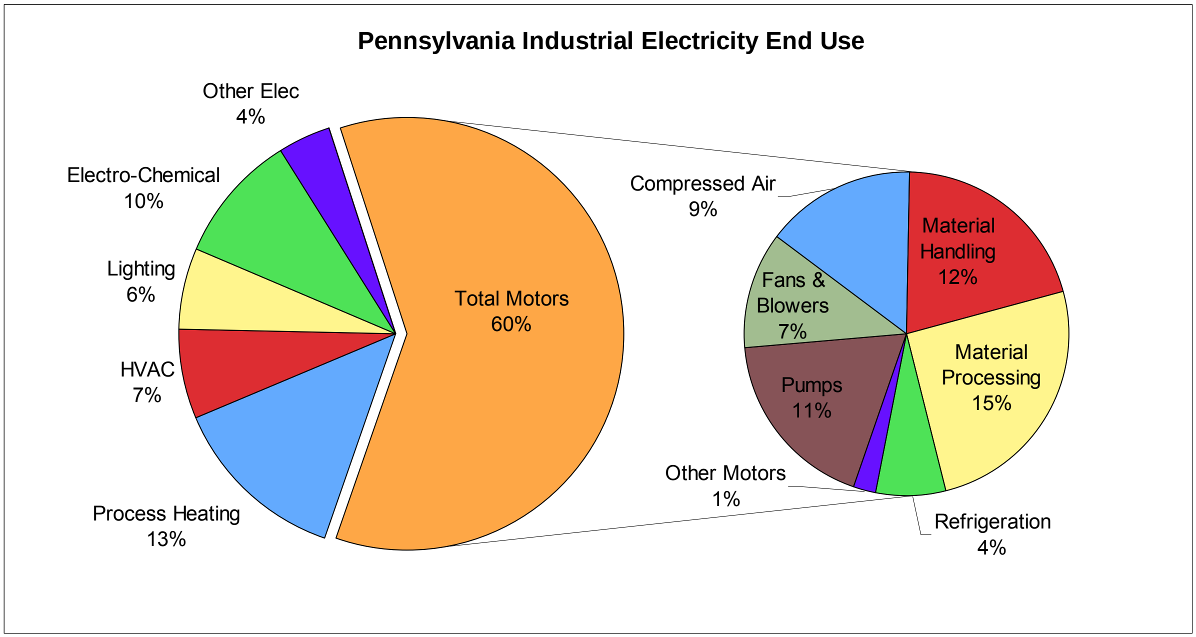
Figure B-1. Percent of Total Electricity Consumption by Motor Systems



Source: XENERGY (1998)

Motors are used for many diverse applications from fluid applications (pumps, fans, and air and refrigeration compressors), to materials handling and processing (conveyors, machine tools and other processing equipment). The distribution of these motor uses varies significantly by industry, with material processing being the largest consumer in the sector. Figure B-2 shows the total weighted average of end-use electricity consumption in Pennsylvania with a breakdown of motors use in the state.

Figure B-2. Weighted Average of Total Industrial Electricity End-Uses in Pennsylvania with Breakdown of Industrial Motor System End-Uses

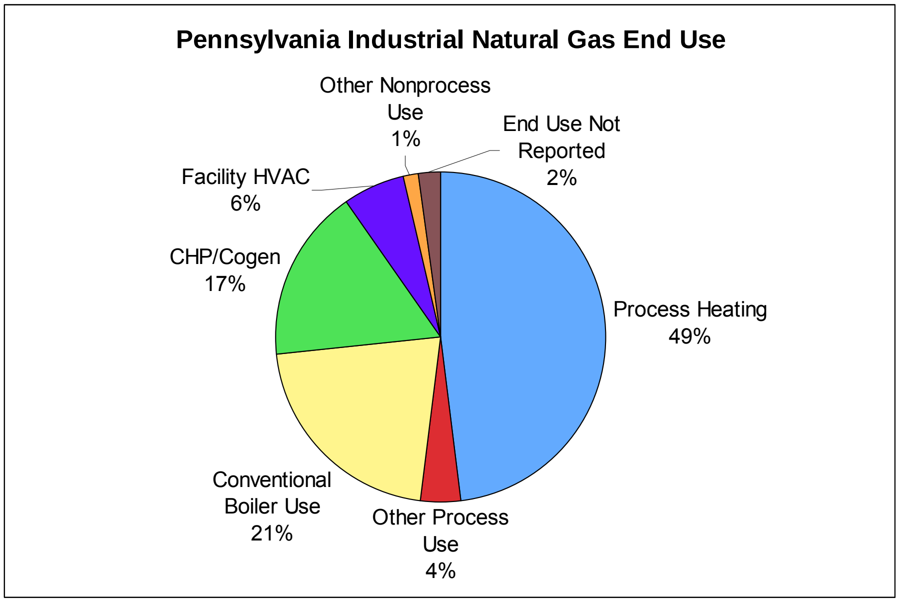


While lighting and space conditioning represent a relatively small share of the overall industrial sector electricity consumption, they are important in some of the key industries found in the region such as transportation equipment manufacturing and computer and electronics manufacturing, and the electricity savings potential can be significant.

Industrial Natural Gas End Uses

A similar methodology was used to determine industrial natural gas end use. The MECS survey (EIA 2005) provided both end use categories and nationwide consumption by industry, which was then applied to the actual industry mix in Pennsylvania.

Figure B-3. Pennsylvania Industrial Natural Gas End Use



Direct process heating is responsible for almost 50% of natural gas use in Pennsylvania, followed by boilers, which account for almost 40%.

Overview of Efficiency Measures Analyzed

The first step in our technology assessment was to collect limited information on a broad "universe" of potential technologies. Our key sources of information included the U.S. Department of Energy, Office of Industrial Technologies; the Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET); Lawrence Berkeley National Laboratory (LBNL) and American Council for an Energy-Efficient Economy reports; information from NYSERDA; and Itron (Itron 2006). We did not collect any primary data on technology performance.

Oftentimes, no one source provided all of the information we sought for our assessment (energy use, energy savings compared to average current technology, investment cost, operating cost savings, lifetime, etc.). We therefore made our best effort to combine readily available information along with expert judgment where necessary.

We sought to identify technologies that could have a large potential impact in terms of saving energy. These may be technologies that are specific to one process or one industry sector, or so-called "cross-cutting" technologies that are applicable to a variety of sectors. In estimating energy savings, we first identified the specific energy savings of each technology by comparing the energy used by the efficient technology to the energy required by current processes. Our second step was to "scale up" this savings estimate to see how much energy savings—for industry overall—this technology would achieve. For the most part, we derived specific energy savings information from the various technology assessment studies noted above.

In scaling up the technology-specific energy savings, we relied on our general knowledge of the various industrial processes to which this technology could be applied. We also took into account structural limitations to the penetration of the technology. Additionally, we recognized that market penetration, in the absence of significant policy support, can take time given the slowness of stock turnover in many industrial facilities.

Electricity Measures

We identified 14 measures that were cost effective at the average projected industrial electricity rates in Pennsylvania of $0.07/kWh (Table B-16). The cost and performance of these measures has been developed over the past decade by ACEEE from research into the individual measures and review of past project performance. The costs of many of these measures has increased in recent years as a result of significant increases in key commodity costs such as copper, steel and aluminum, as well as overall manufacturing costs due to energy prices and market pressures. The estimates presented in Table C.6 represent ACEEE most current estimates. We present the full normalized installed measure cost (i.e., the full cost required to install a measure per unit of saved energy) as well as the levelized cost (i.e., the annual cost of the measure amortized over the life of the measure).

Table B-16. Cost and Performance of Industrial Electric Measures

		Cost of Saved Energy		
Measure	Measure Life	Installed $/kWh	Levelized $/kWh	Annual Savings for End-Use
Sensors & Controls	15	$0.145	$0.014	3%
EIS	15	$0.635	$0.061	1%
Duct/Pipe insulation	20	$0.653	$0.052	20%
Electric supply	15	$0.104	$0.010	3%
Lighting	15	$0.212	$0.020	23%
Advanced efficient motors	25	$0.491	$0.035	6%
Motor management	5	$0.079	$0.018	1%
Lubricants	1	$0.000	$0.000	3%
Motor system optimization	15	$0.097	$0.009	1%
Compressed air manage	1	$0.000	$0.000	17%
Compressed air -advanced	15	$0.001	$0.000	4%
Pumps	15	$0.083	$0.008	20%
Fans	15	$0.249	$0.024	6%
Refrigeration	15	$0.034	$0.003	10%

In addition, we estimated the average normalized cost of industrial energy efficiency investments to be $0.26/kWh saved. This estimate was arrived at by estimating the sum of the annual incremental savings for each measure in each industry based on end-use energy distribution and dividing the corresponding total investment required.

Natural Gas Measures

We identified 35 measures that were cost effective at the average projected industrial natural gas rate in Pennsylvania of $11.72/mmBtu (Table B-17). The cost and performance of these measures were taken from a 2006 Itron report. We present the full normalized installed measure cost (i.e., the full cost required to install a measure per unit of saved energy) as well as the levelized cost (i.e., the annual cost of the measure amortized over the life of the measure).

Table B-17. Cost and Performance of Industrial Natural Gas Measures

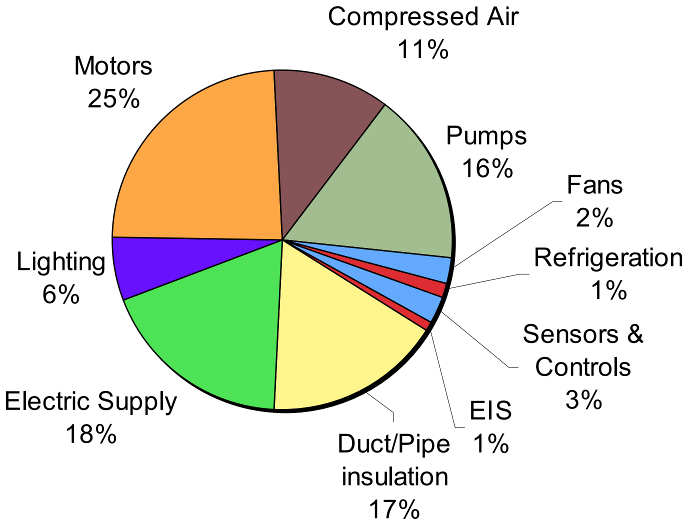
Measure	Measure Life	Installed Cost ($/mmBtu Saved)	Levelized Cost ($/mmBtu Saved)	Annual Savings for End-Use
Boiler Measures				
Improved process control	15	$1.23	$0.12	3%
Maintain boilers	2	$0.02	$0.01	10%
Flue gas heat recovery/economizer	15	$3.48	$0.34	2%
Blowdown steam heat recovery	15	$3.06	$0.29	1%
Upgrade burner efficiency	20	$2.50	$0.20	1%
Water treatment	10	$0.63	$0.08	1%
Load control	15	$1.36	$0.13	4%
Improved insulation	15	$6.55	$0.63	8%
Steam trap maintenance	2	$0.84	$0.45	13%
Automatic steam trap monitoring	15	$3.41	$0.33	5%
Leak repair	2	$0.22	$0.12	4%
Condensate return	15	$9.57	$0.92	10%
HVAC Measures				
Improve ceiling insulation	20	$85.70	$6.88	24%
Install HE(95%) cond furnace/boiler	20	$37.88	$3.04	18%
Stack heat exchanger	20	$18.41	$1.48	5%
Duct insulation	20	$3.52	$0.28	2%
EMS install	20	$31.79	$2.55	10%
EMS optimization	5	$0.30	$0.07	1%
Process Heat Measures				
Process Controls & Management	8	$3.33	$0.51	5%
Heat Recovery	20	$92.06	$7.39	20%
Efficient burners	10	$14.27	$1.85	18%
Process integration	15	$87.04	$8.39	17%
Efficient drying	20	$61.55	$4.94	17%
Closed hood	15	$34.82	$3.35	5%
Extended nip press	20	$92.59	$7.43	16%
Improved separation processes	20	$26.30	$2.11	10%
Flare gas controls and recovery	15	$87.04	$8.39	50%
Fouling control	5	$1.77	$0.41	7%
Efficient furnaces	20	$13.89	$1.11	6%
Oxyfuel	20	$63.13	$5.07	20%
Batch cullet preheating	15	$27.85	$2.68	16%
Preventative maintenance	5	$0.30	$0.07	2%
Combustion controls	8	$5.32	$0.82	8%
Optimize furnace operations	10	$9.52	$1.23	10%
Insulation/reduce heat losses	15	$29.79	$2.87	5%

We estimated the average normalized cost of industrial energy efficiency investments to be $20.11/mmBtu saved. This estimate was arrived at by estimating the sum of the annual incremental savings for each measure in each industry based on end-use energy distribution and dividing the corresponding total investment required.

Potential for Energy Savings

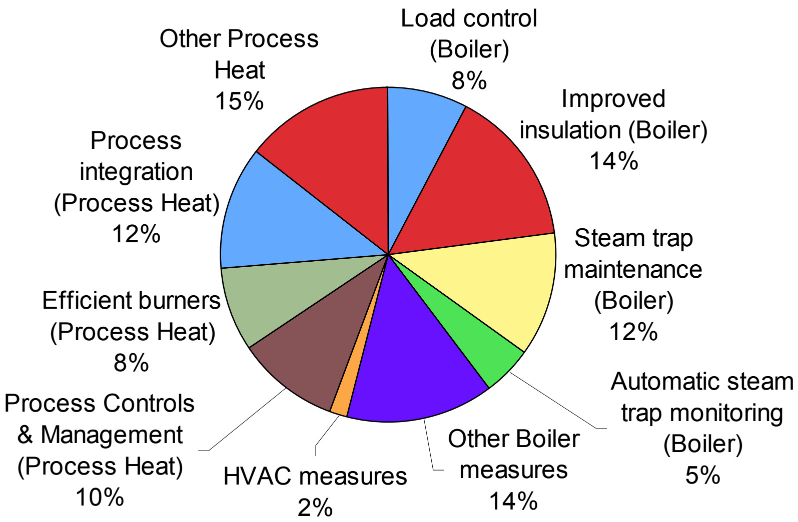
In Pennsylvania, a diverse set of efficiency measures will provide electricity savings for industry. The application of these measures contributes to total economic electric savings potential of 16%. These savings are distributed as presented in Figure B-4.

Figure B-4. Fraction of Savings Electricity Potential by Measure



The total natural gas savings potential for the state of Pennsylvania is about 12%. These savings are distributed as presented in Figure B-5.

Figure B-5. Fraction of Savings Natural Gas Potential by Measure



In addition, this analysis did not consider process-specific efficiency measures that would be applied at the individual site level because available data does not allow this level of analysis. However, based on experience from site assessments by U.S. Department of Energy and others entities, we would anticipate an additional economic savings of 5-10%, primarily at large energy intensive manufacturing facilities. Therefore, the overall economic industrial efficiency resource opportunity for electricity and natural gas is on the order of 21-26% and 17%-22%, respectively.

APPENDIX C – ENERGY EFFICIENCY POLICY ANALYSIS

Statewide Efficiency Policy Potential

A suite of energy efficiency policies was considered for potential energy savings impacts, associated costs, and consumer benefits. Unlike the cost-effective efficiency potential assessment, the policy analysis assessment considers reasonable ramp-up rates of a specific set of programs and policies. Estimated annual energy savings for odd years between 2007 and 2025 are shown in the following tables for electricity (Table C-1), peak demand impacts (Table C-2), natural gas savings (Table C-3) and fuel oil savings (Table C-4). Estimated annual costs for odd years are shown in Table C-5. Methodology for each policy is described below.

Appliance Efficiency Standards

Federal appliance efficiency standards include those set in EISA 2007 (because savings for these are not yet accounted for in the state energy forecast) and those that are directed to be set by DOE over the next several years. Energy savings and consumer investments from efficiency standards are based on a forthcoming analysis by ACEEE and ASAP. Opportunities for state appliance efficiency standards include: Furnace fans; fluorescent fixtures; DVD players; compact audio equipment; portable electric spas; water dispensers; hot food holding cabinets, TVs; and portable lighting fixtures. We estimate savings from these new standards, effective 2010 (except 2013 for furnace fans), and costs based on a forthcoming analysis by ACEEE and ASAP.

Building Energy Codes

We assume the following for this policy analysis: the IECC 2009 is adopted, which goes into effect 2011; the IECC 2012 is adopted and goes into effect in 2014; and the IECC 2018 becomes effective 2020. We estimate that these codes achieve a 15%, 30%, and 50% energy savings improvement beyond IECC 2006 requirements, respectively. Savings apply only to end-uses covered under building codes, which are HVAC, lighting, and water heating end-uses, and the energy consumption percentage for these end-uses are based on the economic potential analysis. We assume compliance and training efforts in the state allow enforcement of each code to start at 70% compliance in the first year, 80% in second year, and 90% in the third and subsequent years. Energy projections for the new construction market are determined from the energy reference case in Appendix A and adjusted new housing growth projections for the residential sector from Moody's Economy.com and employment projections as a proxy for growth in the commercial sector (Economy.com 2008). For costs, we assume those determined by the economic efficiency potential for the buildings analysis. We assume $1.5 million dollars per year to implement and enforce codes, based on recommendations in New York (NY DPS 2007). This is similar to estimates from other states that new program costs run 2-3% of building costs.

Energy Efficiency Resource Standard

For this analysis, we assume electric utilities meet the required cumulative annual savings targets of 1% in 2011 and 3% in 2013 (as a percentage of 2010-year sales) from the 5-year programs filed in 2009. We assume utilities then file new 5-year programs which achieve incremental annual savings of 1.25%, growing to 1.5% per year, relative to prior-year sales, and 1.75% by 2022. We adjust the sales forecast for each of these benchmark years based on assumed savings from previous years' EERS savings to determine an "adjusted reference case". By 2025, utility efficiency programs are meeting 16% of the projected electricity needs of the state. This scenario also assumes that natural gas savings targets are established, starting at 0.25% in 2010, ramping up to 0.5% in 2013, 0.75% in 2016, and 1% in 2018, which continues per year through 2025. We assume investment costs for energy-efficient technologies and practices from the findings of the economic potential analysis.

Combined Heat & Power Financial Incentives

This scenario assumes that the effective cost of installing CHP is reduced by $500 per kW as a result of reduced project uncertainty and delays as a result of removal of market barriers as described in the text. See Appendix E for a full description of the CHP analysis.

Industrial Initiative

This scenario assumes that a statewide industrial initiative is pursued and that the number of industrial assessments ramps up from 50 in the first year to 100 in the second and 200 in the third year and each following year. We assume that each assessment identifies 20% electricity savings, and that 50% of identified savings are implemented. Based on actual data from Industrial Assessment Centers (IAC) and adjusting upward to account for targeting larger industries, these 200 audits could achieve cumulative savings of roughly 10% of Pennsylvania's manufacturing energy use by 2025. Because of time lag between the audit and implementation, we assume that investment and savings for each year would occur over two years, while program costs would begin in year zero. Program costs for the IAC program are about $1 for every $10 saved by industry. We factor in another $0.25 per $10 saved to account for additional education costs.

Consumer Financial Incentives

Pennsylvania’s Alternative Energy Investment Fund appropriates about $100 million over next 8 fiscal years to the Consumer Energy Program, which provides loans, grants, reimbursements and rebates to individuals and small businesses for consumer energy conservation projects. To estimate energy savings from this program and expanded efforts over the study time period, we assume half of the existing funding goes toward oil-savings measures (because these consumers are not directly targeted by the EERS requirements in the policy scenario), while 30% and 20% of the funds go to natural gas and electricity-saving measures, respectively. We assume that over time the program shifts away from customers that heat with natural gas or electricity and focuses solely on customers that heat with fuel oil. Possible funding to support expansion of this program could come from another bond issue by the state, by future revenues from a federal carbon cap and trade program, or through a small tax on fuel oil. We assume that funding for oil-savings programs continue at $24 million per year, assuming a tax of two cents per gallon of oil consumed.

State and Local Facilities: Energy Savings Performance Contracting

In our energy efficiency policy scenario, we estimate that the ESPC program requirements are established so that the remaining 80% of state public building buildings (in terms of floorspace) participate in an ESPC project by 2025 and achieve an average 20% savings per facility. The initiative is also assumed to be expanded to reach the local buildings market, which ramps up to meet 80% of the market by 2025. Share of public facilities of the state’s commercial building stock are estimated from CBECS (EIA 2006b) and costs are determined from the commercial building economic potential analysis.

Projection of Policy Case Supply Prices and Electricity Avoided Costs

Introduction

This section presents projections developed by Synapse Energy Economics of Policy Case electricity supply prices and avoided costs for Pennsylvania. The projections are outputs from the electricity costing model that Synapse Energy Economics has developed for this project. The structure of the model and all inputs to the model except the load forecast are described in Appendix A. ACEEE provided the Policy Case Load Forecast.

Caveats - The projections of production costs and avoided costs presented in this section are based upon a number of simplifying and conservative assumptions that the stakeholder group consider reasonable for the purpose of this high-level policy study. These simplifications include use of a single annual average avoided energy cost to evaluate the economics of energy *efficiency measures rather than different avoided energy costs for energy efficiency measures with different load shapes.*

Policy Case Electricity Supply Prices

The Policy Case load forecast, supply forecast, and supply prices are presented in Table C-6. The supply forecast exceeds the load forecast by the level of estimated losses in transmission and distribution. The supply prices include the projected incremental generation costs each year, the retail margin each year and the resulting total average retail rate.

Avoided Electricity Costs

The avoided costs are presented in Table C-7. The avoided capacity costs are presented in $/kw-year while the avoided electric energy costs are given in ¢/kwh.

Table C-1. Summary of Annual Electricity Savings Potential from Energy Efficiency Policies (GWh)

		2007	**2009**	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2025**
	Electricity Savings (GWh)										
	Reference Case	**151,177**	**154,778**	**158,511**	**162,049**	**166,180**	**168,595**	**173,977**	**177,670**	**182,316**	**186,841**
1	Appliance Efficiency Standards - Federal		95	240	1,731	3,526	4,488	5,065	5,966	6,437	6,877
2	Appliance Efficiency Standards - State		-	187	482	876	1,244	1,606	1,822	2,006	2,188
3	Building Energy Codes		-	40	119	260	455	671	982	1,380	1,811
4	Energy Efficiency Resource Standard (EERS)		-	1,566	4,699	8,191	12,439	17,004	21,561	26,096	29,405
	Residential Buildings Programs	-	-	*706*	*1,986*	*3,391*	*5,188*	*7,150*	*8,835*	*10,714*	*12,052*
	Commercial Buildings Programs	-	-	*624*	*1,695*	*2,785*	*4,239*	*5,844*	*6,866*	*8,313*	*9,536*
5	*Industrial Initiative*	-	-	*178*	*800*	*1,511*	*2,222*	*2,933*	*3,644*	*4,355*	*5,066*
6	*Combined Heat and Power*	-	-	*59*	*217*	*504*	*790*	*1,077*	*2,215*	*2,715*	*2,752*
7	Consumer Financial Incentives		21	68	103	114	118	118	118	69	31
8	State and Local Facilities		106	319	531	744	956	1,169	1,381	1,594	1,806
	Total EE Savings	**0**	**222**	**2,421**	**7,664**	**13,711**	**19,700**	**25,633**	**31,831**	**37,581**	**42,119**
%	**% Savings from Efficiency**		**0.1%**	**1.5%**	**4.7%**	**8.3%**	**12%**	**15%**	**18%**	**21%**	**23%**
9	On-Site PV	0	9	32	73	147	282	527	974	1,758	3,095
	Total Savings plus on-site solar	**0**	**232**	**2,453**	**7,737**	**13,858**	**19,982**	**26,159**	**32,804**	**39,339**	**45,214**
%	**% Savings from Efficiency and on-site PV**	0%	0.1%	1.5%	4.8%	8.3%	12%	15%	18%	22%	24%
	Adjusted Reference Case	**151,177**	**154,555**	**156,090**	**154,385**	**152,469**	**148,894**	**148,344**	**145,840**	**144,736**	**144,721**

Table C-2. Summary of Annual Peak Demand Savings Potential from Efficiency and Demand Response Policies (MW)

		2007	2009	2011	2013	2015	2017	2019	2021	2023	2025
	Peak Demand Reductions (MW)										
	Reference Case	**33,391**	**34,439**	**35,269**	**36,057**	**36,976**	**37,513**	**38,710**	**39,532**	**40,566**	**41,573**
1	Appliance Efficiency Standards - Federal	-	27	68	490	998	1,211	1,424	1,660	1,791	1,914
2	Appliance Efficiency Standards - State	-	-	33	86	156	229	302	355	388	420
3	Building Energy Codes	-	-	9	26	58	101	149	218	307	403
4	Energy Efficiency Resource Standard (EERS)	-	-	347	1,031	1,815	2,851	3,873	4,514	5,457	6,143
	Residential Buildings Programs	-	-	*157*	*442*	*754*	*1,154*	*1,591*	*1,966*	*2,384*	*2,682*
	Commercial Buildings Programs	-	-	*139*	*377*	*620*	*943*	*1,300*	*1,528*	*1,850*	*2,122*
5	*Industrial Initiative*	-	-	*30*	*133*	*252*	*371*	*489*	*608*	*727*	*845*
6	*Combined Heat and Power*	-	-	*21*	*79*	*189*	*383*	*493*	*412*	*497*	*495*
7	Consumer Financial Incentives	-	5	15	23	25	26	26	26	15	7
8	State and Local Facilities	-	24	71	118	165	213	260	307	355	402
	Total EE Savings	-	55	543	1,775	3,218	4,632	6,036	7,081	8,313	9,289
%	**% Savings from Efficiency**	0%	0%	2%	5%	9%	12%	16%	18%	20%	22%
9	Demand Response	-	-	443	1,132	2,313	3,745	4,802	4,882	4,981	5,077
	% Savings from DR	0%	0%	1%	3%	6%	10%	12%	12%	12%	12%
	Total Efficiency and DR Peak Reductions	0%	0%	3%	8%	15%	22%	28%	30%	33%	35%
	Adjusted Reference Case	**33,391**	**34,383**	**34,283**	**33,150**	**31,445**	**29,136**	**27,873**	**27,569**	**27,272**	**27,206**

Table C-3. Summary of Annual Natural Gas Savings Potential from Efficiency Policies (BBtu)

		2007	2009	2011	2013	2015	2017	2019	2021	2023	2025
	Natural Gas Savings (BBtu)										
	Reference Case	**586,652**	**595,283**	**602,730**	**605,916**	**609,537**	**612,410**	**628,656**	**625,507**	**627,537**	**637,547**
1	Appliance Efficiency Standards - Federal		-	7	244	1,318	3,061	4,803	6,544	8,257	9,939
2	Appliance Efficiency Standards - State		-	-	-	-	-	-	-	-	-
3	Building Energy Codes		-	201	647	1,473	2,566	3,750	5,420	7,456	9,555
4	Energy Efficiency Resource Standard (EERS)		-	2,967	7,476	13,533	22,696	34,861	47,259	58,394	69,934
	Residential Buildings Programs	-	-	*1,245*	*2,076*	*3,568*	*6,924*	*12,081*	*17,377*	*21,916*	*26,699*
	Commercial Buildings Programs	-	-	*830*	*1,384*	*2,379*	*4,616*	*8,054*	*11,585*	*14,611*	*17,799*
5	*Industrial Initiative*	-	-	*893*	*4,016*	*7,586*	*11,156*	*14,726*	*18,296*	*21,866*	*25,436*
6	*Combined Heat and Power*										
7	Consumer Financial Incentives		404	1,213	1,629	1,910	2,090	2,270	2,449	1,775	1,371
8	State and Local Facilities		263	788	1,313	1,838	2,363	2,888	3,413	3,938	4,464
	Total EE Savings	**0**	**667**	**5,176**	**11,309**	**20,071**	**32,776**	**48,572**	**65,085**	**79,820**	**95,263**
%	**% Savings from Efficiency**	**0%**	**0%**	**1%**	**2%**	**3%**	**5%**	**8%**	**10%**	**13%**	**15%**
	Adjusted Reference Case	**586,652**	**594,616**	**597,554**	**594,607**	**589,465**	**579,634**	**580,083**	**560,422**	**547,717**	**542,284**

Table C-4. Summary of Annual Fuel Oil Savings Potential from Efficiency Policies (Million Gallons)

		2007	2009	2011	2013	2015	2017	2019	2021	2023	2025
	Fuel Oil Savings (Mil. Gallons)										
	Reference Case	**1,234**	**1,206**	**1,206**	**1,215**	**1,207**	**1,190**	**1,169**	**1,150**	**1,132**	**1,113**
1	Appliance Efficiency Standards - Federal	-	-	-	0	0	0	0	0	0	0.3
2	Appliance Efficiency Standards - State	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	Building Energy Codes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	Energy Efficiency Resource Standard (EERS)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	Consumer Financial Incentives	-	1	5	13	27	46	66	85	101	115
8	State and Local Facilities	-	1	2	3	4	5	6	7	8	10
	Total EE Savings	-	1	7	16	31	52	72	93	110	124
%	**% Savings from Efficiency**	0%	0%	1%	1%	3%	4%	6%	8%	10%	11%
	Adjusted Reference Case	**1,234**	**1,204**	**1,199**	**1,199**	**1,176**	**1,139**	**1,097**	**1,058**	**1,022**	**989**

Table C-5. Summary of Total Annual Costs from Efficiency Policies (Million 2006$)

		2007	2009	2011	2013	2015	2017	2019	2021	2023	2025
	Total Annual Investment Costs										
1	Appliance Efficiency Standards - Federal	$0	$7	$24	$160	$284	$329	$329	$351	$351	$351
2	Appliance Efficiency Standards - State	$0	$0	$86	$100	$100	$100	$100	$100	$100	$100
3	Building Energy Codes	$0	$2	$28	$35	$65	$83	$89	$134	$154	$161
4	Energy Efficiency Resource Standard (EERS)	$0	$1	$271	$580	$713	$933	$1,013	$979	$1,111	$1,158
	Residential Buildings Programs	*$0*	*$0*	*$150*	*$263*	*$332*	*$465*	*$519*	*$496*	*$585*	*$598*
	Commercial Buildings Programs	*$0*	*$0*	*$49*	*$76*	*$99*	*$143*	*$162*	*$144*	*$183*	*$200*
5	*Industrial Initiative*	*$0*	*$1*	*$54*	*$133*	*$133*	*$133*	*$133*	*$133*	*$133*	*$158*
6	*Combined Heat and Power*	*$0*	*$0*	*$19*	*$108*	*$150*	*$191*	*$199*	*$205*	*$210*	*$201*
7	Consumer Financial Incentives	$0	$47	$62	$78	$104	$129	$127	$125	$123	$121
8	State and Local Facilities	$0	$29	$29	$29	$29	$29	$29	$29	$29	$29
	Total Costs	*$0*	*$85*	*$500*	*$981*	*$1,296*	*$1,603*	*$1,688*	*$1,718*	*$1,869*	*$1,919*

Note: Total costs include: (1) customer/private investments; (2) program incentives; and (3) program administrative/marketing costs.

Table C-6. Efficiency Policy Case Load and Supply Forecast and Supply Prices

All costs in constant 2006 dollars.

CASE:	**PA Policy Case - 2/24/09**																	
Category	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Load Forecast																		
Retail Energy	GWh	154,562	155,373	156,110	156,032	154,418	152,896	152,022	151,172	147,754	148,129	146,745	146,032	143,628	143,033	142,497	142,089	142,317
Retail Demand	MW	31,232	31,190	31,144	30,922	30,117	29,392	28,560	27,789	26,445	25,591	25,273	25,380	24,970	24,832	24,663	24,520	24,564
Supply Forecast																		
Capacity Requirement	MW	39,543	39,489	39,431	39,150	38,131	37,212	36,159	35,183	33,482	32,401	31,998	32,133	31,614	31,439	31,225	31,045	31,101
Capacity Sources																		
In-State Capacity	MW	45,135	45,251	45,725	44,983	44,825	44,063	43,302	43,001	42,200	41,456	40,677	39,907	39,476	38,767	38,057	37,347	36,637
Out-of-State Capacity	MW	-5,592	-5,762	-6,295	-5,833	-6,695	-6,850	-7,143	-7,818	-8,718	-9,055	-8,679	-7,773	-7,862	-7,327	-6,832	-6,302	-5,536
Total Capacity Provided	MW	39,543	39,489	39,431	39,150	38,131	37,212	36,159	35,183	33,482	32,401	31,998	32,133	31,614	31,439	31,225	31,045	31,101
Energy Requirement	GWh	170,164	171,057	171,869	171,782	170,006	168,330	167,368	166,432	162,669	163,082	161,559	160,773	158,127	157,471	156,882	156,432	156,683
Energy Sources																		
In-State Generation	GWh	228,558	229,680	233,799	231,712	231,675	229,391	227,100	227,988	225,361	223,220	220,783	218,420	218,377	216,412	214,448	212,483	210,518
Out-of-State Generation	GWh	-58,394	-58,622	-61,930	-59,930	-61,669	-61,061	-59,732	-61,556	-62,692	-60,138	-59,225	-57,647	-60,250	-58,941	-57,566	-56,051	-53,835
Total Energy Provided	GWh	170,164	171,057	171,869	171,782	170,006	168,330	167,368	166,432	162,669	163,082	161,559	160,773	158,127	157,471	156,882	156,432	156,683
Supply Price Forecast																		
Average Production Cost	¢/kWh	5.98	6.08	6.14	6.12	6.98	7.09	7.21	7.37	7.48	7.59	7.69	7.80	7.92	8.03	8.14	8.24	8.34
Retail Margin	¢/kWh	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92
Average Retail Rate	¢/kWh	8.90	9.00	9.05	9.03	9.90	10.00	10.13	10.28	10.40	10.50	10.61	10.71	10.84	10.95	11.05	11.15	11.26

Table C-7. Projections of Avoided Electricity Costs in Energy Efficiency Policy Scenario

All costs in constant 2006 dollars.

CASE:	**PA Policy Case - 2/24/09**																	
Category	Units	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Avoided Costs by costing period																		
Avoided Resource Cost	¢/kWh	6.47	6.95	6.83	7.06	7.67	8.56	8.75	8.98	9.07	9.16	9.25	9.33	9.46	9.57	9.67	9.78	9.93
Avoided Capacity Cost	$/kW-yr	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11	76.11
	¢/kWh	1.54	1.53	1.52	1.51	1.48	1.46	1.43	1.40	1.36	1.31	1.31	1.32	1.32	1.32	1.32	1.31	1.31
Avoided Energy Only Cost	¢/kWh	4.93	5.43	5.31	5.55	6.18	7.10	7.33	7.58	7.71	7.85	7.94	8.01	8.13	8.25	8.35	8.46	8.61

Notes: Avoided Resource Costs represent avoided production costs (fuel, O&M, CO2) for all resources, plus levelized capital costs for new resources.

Avoided Capacity Cost in $/kw-yr is converted into an energy cost equivalent (c/kWh) using the system load factor.

Avoided Energy Cost represents Total Avoided Resource Cost less Avoided Capacity Cost expressed as energy cost equivalent.

C.3 Emissions Impacts Methodology

To estimate annual carbon dioxide emissions reductions from the energy efficiency policy scenario, we first obtained data from the reference case projected electricity generation and carbon dioxide (CO2) emissions (2007-2025) for Pennsylvania from Synapse Energy Economics' electricity supply projections. We then calculated a CO2 *output emission rate*, defined as the ratio of emissions (lbs) to electricity generation (MWh). Using data from the Environmental Protection Agency's eGRID on subregion, non-baseload, or marginal, emission rates (EPA 2008) and converting to standard tons, we calculated a *net marginal emissions factor* (tons CO2/MWh) for Pennsylvania, which is the *output emission rate* multiplied the ratio of marginal to average emission rates for eGRID's subregion. We then multiplied the *net marginal emissions factor* by the estimated annual electricity savings in Pennsylvania from the energy efficiency policy scenario to determine CO2 emissions reductions from reduced electricity consumption. We then estimated CO2 emissions reductions from natural gas and fuel oil energy savings in the policy scenario using emission rates from the Energy Information Administration (EIA 2008).

C.4. Philadelphia and Pittsburgh Metro Regions

To estimate regional energy savings potential for policy programs enacted in Philadelphia and Pittsburgh, we followed a number of different methodologies for the various policy recommendations. For appliance efficiency standards and EERS, we allocated statewide estimates by region by calculating the amount of energy used by each region (by sector) as a percentage of the state and then multiplied this percentage by statewide energy savings for each program. This method provides a close approximation of the energy savings each region can expect from implementing the programs. To calculate the percentage of energy used by Philadelphia and Pittsburgh, we divided energy usage data from our reference forecast for each city by the usage data from the state reference forecast. We then multiplied the resulting percentages by the statewide energy savings data for each of the policy programs, resulting in the savings potential for each program for each region. We applied this methodology to the following policy programs: Federal Appliance Efficiency Standards, State Appliance Efficiency Standards, Energy Efficiency Resource Standards (EERS), Consumer Financial Initiatives, and State and Local Facilities. For Building Energy Codes, we followed the same methodology as the statewide estimates using regional data on household growth from Economy.com. For the regional analyses of onsite solar market potential, see Appendix F.

APPENDIX D – DEMAND RESPONSE ANALYSIS

Introduction

This report defines Demand Response (DR), assesses current DR activities in Pennsylvania, identifies policies in the state that impact DR, uses benchmark information to assess DR potential in Pennsylvania, and identifies barriers in the state that might keep DR contributing appropriately to the resource mix that can be used to meet electricity needs. The analysis concludes with identification of policy recommendations regarding DR.

Objectives of this Assessment

This assessment develops estimates of DR potential for Pennsylvania. Potential load reductions from DR are estimated for the residential, commercial, and industrial sectors (see Section 3). The assessment also includes discussions of reductions possible from other DR programs, such as DR rate designs (see Section 3.6).

Role of Demand Response in Pennsylvania's Resource Portfolio

The DR capabilities developed by Pennsylvania utilities will become part of a long-term resource strategy that includes resources such as traditional generation resources, renewable energy, power purchase agreements, options for fuel and capacity, energy efficiency and load management programs. Objectives include meeting future loads at lower cost, diversifying the portfolio to reduce operational and regulatory risk, and allow Pennsylvania customers to better manage their electricity costs. The growth of renewable energy supply (and plans for increased growth) can increase the importance of DR in the portfolio mix. For example, sudden renewable energy supply reductions (e.g., from an abrupt loss in wind) may be mitigated quickly with DR.

Summary of DR Potential Estimates in Pennsylvania

Table 1 shows the resulting load shed reductions possible for Pennsylvania, by sector, for years 2015, 2020, and 2025. Load impacts grow rapidly through 2018 as program implementation takes hold. After 2018, the program impacts increase at the same rate as the forecasted growth in peak demand.

The high scenario DR load potential reduction is within a range of reasonable outcomes in that it has an eleven year rollout period (beginning of 2010 through the end of 2020), providing a relatively long period of time to ramp up and integrate new technologies that support DR. A value nearer to the high scenario than the medium scenario would make a good MW target for a set of DR activities.

The high scenario results show a reduction in peak demand of 2,313MW is possible by 2015 (6.3% of peak demand); 4,860MW is possible by 2020 (13.2% of peak demand); and 5,077MW is possible by 2025 (13.8% of peak demand).

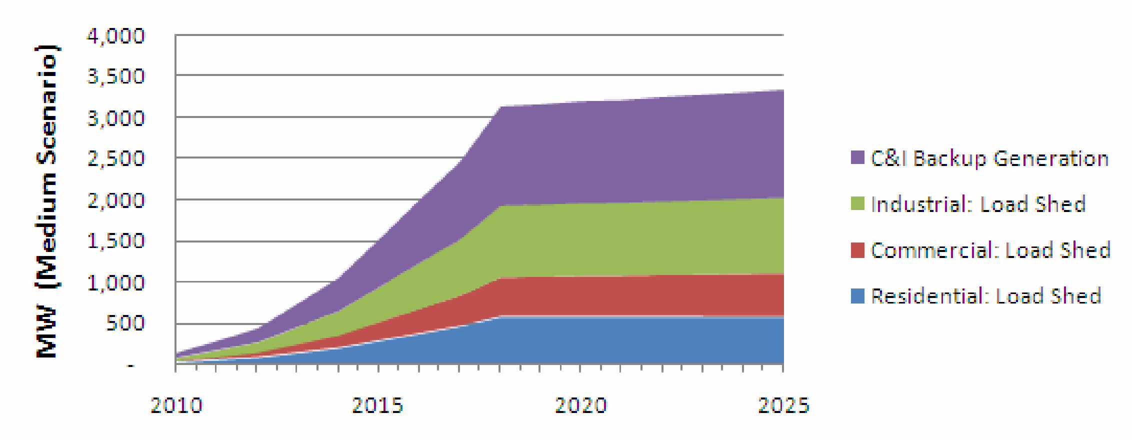
The more conservative medium scenario results show a reduction in peak demand of 1,523MW is possible by 2015 (4.1% of peak demand); 3,199MW is possible by 2020 (8.7% of peak demand); and 3,339MW is possible by 2025 (9.1% of peak demand).

Table D-1. Summary of Potential DR in Pennsylvania, By Sector, for Years 2015, 2020, and 2025[a]

	Low Scenario			Medium Scenario			High Scenario		
	2015	2020	2025	2015	2020	2025	2015	2020	2025
Load Sheds (MW):									
Residential	174	350	347	290	583	578	406	816	809
Commercial	85	184	198	226	491	529	425	920	992
Industrial	189	394	409	425	887	921	755	1,576	1,637
C&I Backup Generation (MW)	436	928	983	582	1,238	1,311	727	1,547	1,639
Total DR Potential (MW)	884	1,856	1,938	1,523	3,199	3,339	2,313	4,860	5,077
DR Potential as % of Total Peak Demand	2.4%	5.1%	5.3%	4.1%	8.7%	9.1%	6.3%	13.2%	13.8%
a. See Section 3 for underlying data and assumptions.									

Figure D-1 shows the resulting load shed reductions possible for Pennsylvania, by sector, from year 2010, when load reductions are expected to begin, through year 2025.

Figure D-1. Potential DR Load Reductions in Pennsylvania by Sector (Medium Scenario)



These estimates reflect the level of effort put forth and utilities are recommended to set targets for the high scenarios. These estimates are based on assumptions regarding growth rates, participation rates, and program design. In developing these DR potential estimates, the integration of DR with select energy efficiency activities was considered to help ensure that load impacts were not double counted. The estimated load reduction per program participant is conservatively estimated to account for increased energy efficiency in the future.

Defining Demand Response

DR focuses on shifting energy from peak periods to off-peak periods and clipping peak demands on days with the highest demands. Within the set of demand-side options, DR focuses on clipping peak demands that may allow for the deferral of new capacity additions, and it can enhance operating reserves available to mitigate system emergencies. Energy efficiency focuses on reducing overall energy consumption with attendant permanent reductions in peak demand growth. Taken together, these two demand-side options can provide opportunities to more efficiently manage growth, provide customers with increased options to manage energy costs, and develop least cost resource plans.

DR is an increasingly important tool for resource planning as power plant siting has grown more difficult and the costs of peak power have increased. Through development of DR capability, utilities can complement existing energy efficiency programs with a set of offerings that provide, at a minimum, 1) enhanced reliability, 2) cost savings, 3) reduced operating risk through resource diversification, and 4) increased opportunities for customers to manage their electric bills.

DR resources are usually grouped into two types: 1) load-curtailment activities where utilities can “call” for load reductions; and 2) price-based incentives which use time-differentiated and/or dispatchable rates to shift load away from peak demand periods and reduce overall peak-period consumption. Interest in both types of DR activities has increased across the country as fuel input prices have increased, environmental compliance costs have become more uncertain, and investment in overall electric infrastructure is needed to support new generation resources.

The mechanisms that utilities may use to achieve load reductions can range from voluntary curtailments to mandatory interruptions. These mechanisms include, but are not limited to:

- Direct load control by the utility using radio frequency or other communications platforms to trigger load devices connected to air conditioners, electric water heaters, and pool pumps;
- Manual load curtailments at commercial and industrial (C&I) facilities, including shutting off production lines and dimming overhead lighting;
- Automated DR (“Auto-DR”) technologies utilizing controls or energy management systems to reduce major C&I loads in a pre-determined manner (e.g., raising temperature set points and reducing lighting loads); and
- Behavior modifications such as raising thermostat set points, deferring electric clothes drying in homes, and reducing lighting loads in commercial facilities.

Rationale for Demand Response

DR alternatives can be implemented to help ensure that a utility continues to provide reliable electric service at the least cost to its customers. Specific drivers often cited for DR include the following:

- **Ensure reliability—**DR provides load reductions on the customer side of the meter that can help alleviate system emergencies and help create a robust resource portfolio of both demand-side and supply-side resources that meet reliability objectives.

- **Reduce supply costs—**DR may be a less expensive option per megawatt than other resource alternatives. DR resources compete directly with supply-side resources in many regions of the country. Portfolios that help lower the increase in customers' expenditures on electricity over time represent an increasingly important attribute from the perspective of many energy customers.

- **Manage operational and economic risk through portfolio diversification—**DR capability is a resource that can diversify peaking capabilities. This creates an alternative means of meeting peak demand and reduces the risk that utilities will suffer financially due to transmission constraints, fuel supply disruptions, or increases in fuel costs.

- **Provide customers with greater control over electric bills –**DR programs would allow customers to save on their electric bills by shifting their consumption away from higher cost hours and/or responding to DR events. The ability to manage increases in energy costs has increased in importance for both residential and commercial customers. Standard residential and commercial tariffs provide customers with relatively few opportunities to manage their bills.

- **Address legislative/regulatory interest in DR –** Recent legislation, Pennsylvania House Bill 2200, calls for peak load reduction, smart meter deployment, and the availability of time-based rates for all customers.

DR is gaining greater acceptance among both utilities and regulators in the United States. A 2006 FERC survey found that 234 “entities” were offering direct load control programs and the FERC’s assessment noted that “there has been a recent upsurge in interest and activity in DR nationally and, in particular, regional markets” (FERC, 2006).[8] The recent proliferation of DR offerings has been promoted in part by utilities hoping to reduce system peaks while offering customers more control over electric bills and in part by regulators. Although federal legislation has not been the driver behind the trend, it is one of many indications, at all levels of government and industry, of the growing support for DR.[9]

Many states experience significant reductions in peak demand from Demand-Side Management (DSM) programs (which include DR programs). Regulatory filings show that California experienced 495 MW in peak demand reductions in 2005 (1% of total peak demand); New York experienced 288 MW reductions in 2005 (1% of total peak demand); and Texas experienced 181 MW in reductions in 2005 (1% of total peak demand) from DSM programs. These results are annual values that do not consider the cumulative (i.e., year-to-year) impacts that accrue over the lifetimes of the conservation measures. Therefore, cumulative percentage reductions in peak demand are much higher than the annual figures stated.

Assessment Methods

As has been shown in numerous other jurisdictions across North America, well-designed DSM programs incorporating DR strategies represent an effective and affordable option for reducing peak demand and meeting growing demand for electricity. This effort estimated conservative peak demand reduction for Pennsylvania using local energy use characteristics, demographics, and forecast peak demand, assuming relatively basic DR strategies comprising responsive reductions in demand. The following research approach was used to conduct the analysis:

- Review of existing information regarding Pennsylvania’s customer base including:
    - Customer counts and average annual energy consumption by market segment;
    - Forecasts of future energy consumption and customer counts by market segment;
    - Previous DSM planning and potential studies.
- Review of additional publicly-available secondary sources including:
    - U.S. DOE’s Commercial Building Energy Consumption Survey (CBECS) and Residential Energy Consumption Survey (RECS) data;
    - Previous studies relevant to the current effort completed by Summit Blue in other regions as well as entities in other jurisdictions.
- Development of baseline profiles for residential and commercial customers. These profiles include current and forecast numbers of customers by market segment and electricity use profiles by segment.
- Incorporation of ACEEE baseline data and reference case into analysis.
- Obtaining state-level data when possible and estimation of information for the State of Pennsylvania, when state-level data was not available.

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[8] The FERC report uses the term “entities” to refer to all types of electric utilities, as well as organizations such as power marketers and curtailment service providers.

[9] The federal Energy Policy Act of 2005 (EPAct) directs the Secretary of Energy to “identify and address barriers to the adoption of demand response programs,” and the Act declares a U.S. policy in support of “State energy policies to provide reliable and affordable demand response services.” EPAct directed FERC to conduct its survey of DR programs and also directed the U.S. Department of Energy to report on the benefits of DR and how to achieve them (DOE, 2006). Separately, a *National Action Plan for Energy Efficiency,* which advocates DR and other efficiency efforts, was developed by more than 50 U.S. companies, government bodies, and other organizations, including co-chairs Diane Munns, President of NARUC and Jim Rogers, President and CEO of Duke Energy (U.S. Environmental Protection Agency, 2006). Other utility industry members of the Leadership Group included Southern Company, AEP, PG&E, TVA, PJM Interconnection, ISO New England, and the California Energy Commission.

- Development of a spreadsheet approach for estimating peak demand reduction potential associated with the DR programs/technologies deemed to be most applicable to Pennsylvania. Estimates are developed for three scenarios—low, medium and high case scenarios.
- Conference calls with ACEEE staff and industry professionals to discuss assessment processes and legislative, regulatory, and other factors specific to the State of Pennsylvania.
- Incorporation of all sources of information and references into report, noting on each figure the source of the information.
- Revision of draft report based on comments from ACEEE, industry specialists and utility commenters.

The DR potential estimated used historical data and experience to obtain curtailment levels. This potential is assumed to be the achievable potential that would be cost effective, given the range of incentives that are typically required and the range of the utilities' avoided costs. A cost-effectiveness analysis was not performed for this study. Sufficient incentives could be provided to customers to encourage load reductions while maintaining a cost-effective program given avoided costs of approximately $76 per kW (based on the analysis reference case).

Commonwealth of Pennsylvania — Background

A sound strategy for development of DR resources requires an understanding of Pennsylvania's demand and resource supply situation, including projected system demand, peak-day load shapes, and existing and planned generation resources and costs.

Pennsylvania utilities serve 5.2 million residential facilities and almost 700,000 non-residential facilities (EIA 2007b), providing power that is expected to have a system peak load of almost 34,000 MW in 2008 (ACEEE base case for Pennsylvania).

Electricity demand in Pennsylvania has grown at a rate of 1.8 percent annually in the past 15 years (PUC 2008c). This is an aggregate figure for all sectors, including industrial, commercial and residential. Average total sales growth from 2002 to 2007 was also 1.8 percent. Aggregate sales in 2007 totaled approximately 149 billion kWh, and are projected to grow at 1.4 percent annually to 2012. This includes a residential growth rate of 1.5 percent, a commercial growth rate of 1.6 percent and an industrial growth rate of 1.1 percent.

The Electric Power Outlook for Pennsylvania 2007-2012 concludes that there is sufficient generation, transmission and distribution capacity to reasonably meet the needs of Pennsylvania consumers for the near future, with generation adequacy concerns beginning in 2013 (PUC 2008b). By 2013, additional capacity resources of 1,500 MW will likely be needed to maintain a 15% reserve margin (PUC 2008b).[10]

Almost all of Pennsylvania is located within the PJM regional transmission organization, the largest power region in the US with installed capacity of over 164,000 MW. PJM covers 11 states including Pennsylvania, New Jersey, Maryland, Delaware, Virginia, and parts of Ohio, Indiana, Illinois, Michigan and North Carolina. See Section 2.2 for a discussion of PJM's DR programs.

Eleven electric distribution companies (EDCs) currently serve the electrical energy needs of the majority of Pennsylvania's homes, businesses and industries. Cooperatives and municipal systems provide service to several rural and urban areas. PECO Energy Company (a subsidiary of Exelon Corporation, based in Philadelphia) and PPL Electric Utilities Corporation (headquartered in

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[10] This forecast does not include thousands of megawatts of "possible capacity additions" identified by the PJM and Midwest ISO generation interconnection queues as projects in service after 2012. These projects are not counted toward meeting reserve requirements as this capacity is not committed to serve regional load

Allentown, PA) are the two largest retailers of electricity in Pennsylvania, providing 37.3 million MWh and 36.5 million MWh, respectively, in 2006 (EIA 2007c). The five largest retailers are the following, with percent contribution in parentheses:

- PECO Energy Company (26%)
- PPL Electric Utilities Corporation (25%)
- West Penn Power Company (Allegany Power) (14%)
- Metropolitan Edison Company (First Energy) (9%)
- Pennsylvania Electric Company (Penelec; First Energy) (9%) (EIA, 2006).

Assessment of Utility DR Activities

Post restructuring in the state, the Pennsylvania Public Utilities Commission (PPUC) established four Sustainable Energy Funds (SEFs) to promote renewable energy, advanced clean energy technologies, and energy conservation. These funds offer financial assistance through providing grants and loans for eligible projects (U.S. DOE 2008).

The PJM Interconnection (PJM), a regional transmission organization (RTO) containing most of the Commonwealth of Pennsylvania, provides opportunities for DR to realize value for demand reductions in the Energy, Capacity, Synchronized Reserve, and Regulation markets. The FERC authorized PJM to provide these opportunities as permanent features of these markets in early 2006 (PJM 2008ba).

The PJM Economic Load Response Program enables customers to voluntarily respond to PJM Locational Marginal Price ("LMP") prices by reducing consumption and receiving a payment for the reduction. The growth of participation by end-use customers since 2002 is significant, with over 225,000 MWh of participation in 2006 (PJM 2008b).

Under the Reliability Pricing Model (RPM), customers can offer DR as a forward capacity resource. DR providers can submit offers to provide a demand reduction as a capacity resource in the forward RPM auctions. In the first annual RPM auction which was held in April 2007 for the 2007/2008 planning period, 127.6 MW of demand response offers were cleared (PJM 2008b).[11]

PJM held a symposium on DR in May, 2007 that was attended by a broad mix of stakeholders and subject matter experts. One of the most prominent themes to emerge from the symposium was the need for coordination between retail and wholesale markets in order to increase DR participation in PJM's markets. The participants at the PJM Symposium on DR identified priority opportunities, which formed the basis of a “Demand Response Roadmap” to guide action (PJM 2008c).

PECO's (Exelon) Smart Returns program is available to federal customers with curtailment capacity of 100 kW or more. Smart Returns has two options:

- <u>The Mandatory Load Reduction program</u> (also called the Active Load Management or Interruptible Load for Reliability (ILR) program) requires that customers reduce load to a firm service level for no more than six hours when requested (with at least one hour's notice) by PECO during periods of system limitations (primarily on summer weekdays, as triggered by the ISO – PJM); credit is provided based on the difference between the firm service level and the facility's peak load contribution (PLC, which is the facility's average peak during PJM's five highest load hours during the summer). PECO has 118 MW available for DR from this program, from 96 commercial and industrial participating customers.
- <u>The Voluntary Load Reduction (VLR) program</u> compensates customers for cutting usage during periods of high energy prices and has two alternatives, day-ahead and day-of, which vary based on the desired lead time to respond to PECO's curtailment calls and the price per energy reduced that is attractive to the facility. The VLR program offers customers bill credits

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[11] It is not known at this time what portion of PJM DR reductions have been fulfilled by Pennsylvania customers.

for the voluntary reductions. Participants are compensated for performance but are not subject to financial penalties if they do not or are otherwise unable to participate in an event. 171 MW are available from this program, from 128 commercial and industrial customers (Kurt Sontag, PECO, Demand Response Program Manager, Email communication, December 10, 2008).

Pennsylvania Power and Light (PPL) is offering a real-time pricing option, the Demand-Side Initiative Rider to large (>1,000 kW) customers through December 31, 2010. PPL provides participating customers with day-ahead hourly market prices for electricity. Participants are then credited or charged at the market price for usage below or above their predetermined customer reference load (CRL) profile. This allows facility operators to schedule the following day's operations accordingly (U.S. DOE, 2008).

Duquesne Light Company offers the Energy Exchange program, wherein participants with a curtailable load of 500 kW or greater can, upon notification by the company, offer to provide specified day-ahead load reductions for between two and twelve hours through a program Web site. If the company offers an attractive price in return (minimum of $0.30/kWh), the customer can accept and Duquesne, which does not own generating capacity itself, will attempt to market the reductions to its primary power supplier. If accepted, the utility again notifies the customer, this time that its offer has been accepted. Curtailments are quantified based on the customer's ten previous days' use (U.S. DOE, 2008).

Assessment of Current State Policies Affecting DR

Many states have put in place renewable portfolio standards (RPS) to ensure that a minimum amount of renewable energy is included in the portfolio of the electricity resources serving a state. Pennsylvania has chosen an alternate path, as reflected in the name of its standards – Alternative Energy Portfolio Standards – and has chosen to include demand side options among the means by which the standards can be met (DRAM, 2005).

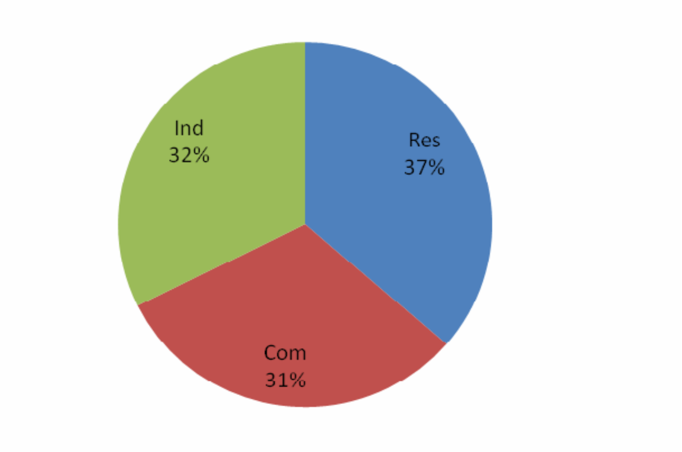
The Demand Side Response Working Group, which was originally created in 2001, was reconvened by Pennsylvania Public Utilities Commission order. By that order, the Commission initiated an investigation into reasonable, cost-effective programs that electric distribution companies, electric generation suppliers, energy services providers and other stakeholders can implement to help retail electric customers conserve energy or use it more efficiently. This investigation was also to include an analysis of needed advanced metering infrastructure and appropriate ratemaking mechanisms that may remove any barriers to the development of energy efficiency, conservation and demand side response. A DSR Working Group Report was released in 2007 (PUC 2007c) which reviewed the issues and provided a sampling of stakeholder comments.

Pennsylvania Act 129, which was signed into law October 15, 2008 by Governor Rendell, calls for peak load reduction, smart meter deployment, and the availability of time-based rates for all customers. The new law requires electric distribution companies to reduce energy consumption by a minimum of 1% by May 31, 2011, increasing to 3% by May 31, 2013, and to reduce peak demand by 4.5% by May 31, 2013.

Energy and Peak Demands

Use of electricity in Pennsylvania is distributed to end use categories as follows: 36% residential, 31% commercial, and 32% industrial sectors (see Figure D-2).

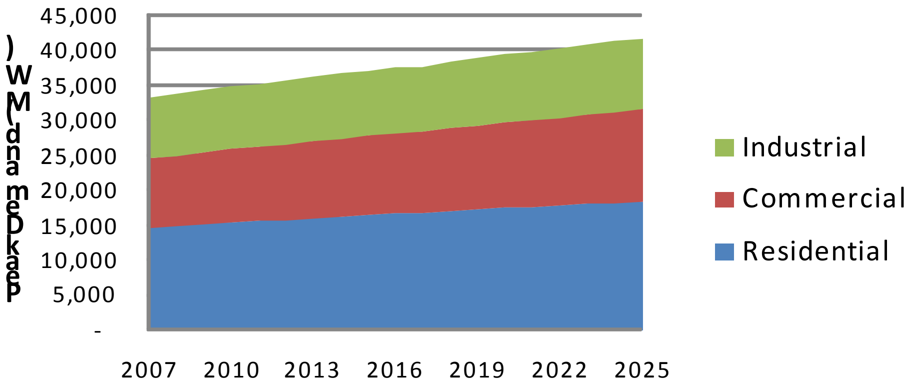
Figure D-2. Electricity Sales in Pennsylvania by Sector (2007)



Source: ACEEE PA Reference Case

In 2007, the total summer peak load was 33,300MW and is projected to grow an average of 1.2% per year through 2025. Figure D-3 displays peak demand by sector. In 2007, residential peak demand was 14,700 MW (44%); commercial was 9,900MW (30%); and industrial was 8,700 MW (26%).

Figure D-3. Peak Demand by Sector in Pennsylvania (MW)



Source: ACEEE Reference Case for Pennsylvania

Smart Grids and Advanced Metering Infrastructure (AMI)

The 2005 Energy Policy Act provisions for Demand Response and Smart Metering has lead to a number of states and utilities piloting and implementing a Smart Grid, or sometimes referred to as Advanced Metering Infrastructure (AMI).

Smart Grid is a transformed electricity transmission and distribution network or "grid" that uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability and safety of power delivery and use. For energy delivery, the Smart Grid has the ability to sense when a part of its system is overloaded and reroute power to reduce that overload and prevent a potential outage situation. The end user is equipped with real-time communication between the consumer and utility allowing optimization of a consumer's energy usage based on environmental and/or price preferences (for example, critical peak pricing and time of use rates).

AMI provides:

- Two-way communication between the utility and the customer through the customer's smart meter.
- More efficient management of customer outages (location, re-routing).
- More accurate meter reading (minute, 15 minute intervals).
- More timely collection efforts (real time).
- Improved efficiency in handling service orders.
- More detailed, timely information about energy use to help customers make informed energy decisions (real time).
- Ability to reduce peak demand.
- More innovative rate options and tools for customers to manage their bills.

Smart Energy Pricing provides:

- Incentives to customers to shift energy away from critical peak periods
- The ability to for customers to save on their electricity bills.
- Lower wholesale prices for capacity and transmission—in the longer term.
- Improved electric system reliability, as demand is moderated.
- Potential to defer new transmission and generation.

The Smart Grid is comprised of multiple communication systems and equipment, which interoperability is crucial. Not all communication protocols are applicable to every utility's geography; therefore, pilots are essential in testing the equipment and communication software for various geographies. Furthermore, the identification of those geographic regions with the best return on investment during a pilot will aid the staged implementation plan. Standards are continuing to be researched through organizations including: 1) IntelliGrid—Created by the Electric Power Research Institute (EPRI); 2) Modern Grid Initiative (MGI) is a collaborative effort between the U.S. Department of Energy (DOE), the National Energy Technology Laboratory (NETL), utilities, consumers, researchers, and other grid stakeholders; 3) Grid 2030—Grid 2030 is a joint vision statement for the U.S. electrical system developed by the electric utility industry, equipment manufacturers, information technology providers, federal and state government agencies, interest groups, universities, and national laboratories; 4) GridWise—a DOE Office of Electricity Delivery and Energy Reliability (OE) program; 5) GridWise Architecture Council (GWAC) was formed by the U.S. Department of Energy; and 6) GridWorks—A DOE OE program.

Principal benefits of Smart Grid technologies for DR include increased participation rates and lower costs. For example, in 2009, Dominion plans to deploy 200,000 smart meters as part of a large demonstration program of smart grid technology in urban and rural areas of Dominion's service territory. Dominion expects to improve customer service and business operations through advanced system control, real-time outage notification, and power quality monitoring. As part of this program, Dominion is deploying a number of smart thermostats for a residential critical peak pricing pilot during the summer of 2008. Dominion will measure customer responsiveness to changing energy prices and the impact on energy demand during peak usage periods (Utility Products 2008).

These developments in technology allowing real time signaling and automated response will improve DR capabilities. However, existing technology exists for successful DR implementation and it is important to point out that there are no technology obstacles to effective DR.

Assessment of DR Potential in Pennsylvania

This section examines and quantifies DR potential in Pennsylvania. Section 6.1 outlines the general DR program categories, while Sections 6.2 and 6.3 outline the DR potential in the residential and commercial /industrial sectors, respectively. Section 6.4 discusses the load reduction potential from backup generation and Section 6.5 explains the issues surrounding rate pricing, even though benefits from this form of DR are not quantified in this analysis. Section 6.6 concludes with a summary of DR potential in Pennsylvania.

Demand Response Program Categories

For the purposes of assessing DR alternatives, the following programs could be employed in Pennsylvania to achieve the DR potential we outlined in this report:

Resource Category	Characteristics
Direct Load Control (DLC)	Direct load control (DLC) programs have typically been mass-market programs directed at residential and small commercial (<100 kW peak demand) air conditioning and other appliances. However, an emerging trend is to target commercial buildings with what has become known as Automated Demand Response or Auto-DR. Increased use and functionality of energy management systems at commercial sites and an increased interest by commercial customers in participating in these programs is driving growth in automated commercial curtailment in response to a utility signal. The common factor in these programs is that they are actuated directly by the utility and require the installation of control and communications infrastructure to facilitate the control process.
Callable Customer Load Response	With this type of program, utilities offer customers incentives to reduce their electric demand for specified periods of time when notified by the utility. These programs include curtailable and interruptible rate programs and demand bidding/buyback programs. Curtailable and interruptible rate programs can be used as “emergency demand response” if the advanced notice requirements are short enough. All customer load response programs require communications protocols to notify customers and appropriate metering to assess customer response.
Scheduled Load Control	This is a class of programs where customers schedule load reductions at pre-determined times and in pre-determined amounts. A variant on this theme is thermal energy storage which employs fixed asset technology to reduce air conditioning loads consistently during peak afternoon load periods.
Time-differentiated Rates	Pricing programs can employ rates that vary over time to encourage customers to reduce their demand for electricity in response to economic signals—in some cases these load reductions can be automated when a price trigger is exceeded. An example is a critical peak price which is “called” by the utility or system operator. In response to this critical price, residential customers can have AC cycling or temperature setbacks automatically deployed. Similar automated responses can be deployed by commercial customers. These rate programs are not analyzed for this assessment, but are further discussed in Section 3.5.

Demand Response for Residential Customers

Air conditioner and other appliance direct load control (DLC) is the most common form of non-price-based DR program in terms of the number of utilities using it and the number of customers enrolled. According to FERC’s 2006 assessment of DR and advanced metering, there are 234 utilities (including municipalities, cooperatives, and related entities) with DLC programs across the United States. Approximately 4.8 million customers are participating in DLC programs across the country (FERC 2006).

The prominent and growing role of air conditioning in creating system peaks makes it a high-profile candidate for DR efforts. The advances in DR technology that make AC load management economically viable make AC load control a high-priority program—one that has been proven reliable and effective at many utilities. Pool pumps are also a relatively easy and non-disruptive load that can be controlled for DR purposes.

Residential Control Strategies

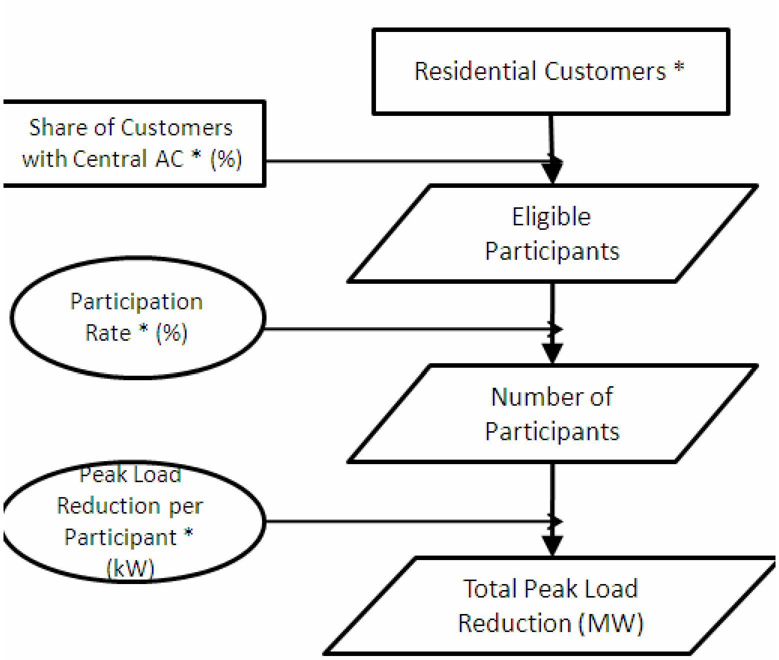
There are two basic types of control strategies: AC cycling and temperature offset. AC cycling limits ACs being on to a certain number of minutes than they otherwise would have been on. Some techniques limit ACs to being on for 50% of the minutes they would otherwise have been on. A temperature offset increases the thermostat setting for a certain period of time, for a certain number of degrees higher than it would have otherwise been set. This essentially causes the AC compressor to cycle as the temperature set-back reduces the AC demand. Sequential thermostat setbacks, i.e., one degree in a hour one, two degrees in hour two, three degrees in hour three, and four degrees in hour four can mimic an AC cycling strategy.

Cycling strategies have evolved where an optimal impact on peak kW demand may be obtained by varying the cycling time across the hours of an event. For example, there may be one hour of pre-cooling followed by 33% cycling in the first hour, 50% cycling in the second hour, 66% cycling in the third hour and dropping back to 33% in the fourth hour. Strategies like this have been deployed in pilot programs at Progress Energy Carolinas (PEC) and in PSE&G's MyPower pilot program. This type of strategy requires that forecasters accurately predict the hour(s) in which the peak system demand will occur.

Assessment of DR Potential in Residential Homes in Pennsylvania

For Pennsylvania, estimates for possible load reductions for residential housing units were obtained by applying the methodology displayed in Figure D-4.

Figure D-4. Residential Peak Load Reduction



* Input data by Single Family and Multi-Family Residences, and by Existing Home and New Construction.

The figure shows how load reductions and participations rates are applied to housing data. Items listed in rectangular shapes are factual inputs; items in circular shapes are assumptions; and items in parallelogram shapes are results.

Load Reductions

Recent surveys show that DLC programs are being implemented by a number of utilities. Load impacts are dependent on many variables. The control strategy used, the outdoor temperature, the time of day, the customer segment, ease of and ability to override control, reliability of communication signals, age and working condition of installed equipment, and local AC use patterns all have significant effects on the load impact. Even within a single program, there is variability in impacts across event days that cannot yet be fully explained. Measuring impacts typically requires expensive monitoring equipment and as a result is often done on small sample sizes.

Even with this variability, a review of reported impacts does show some general consistencies. As expected, impacts increase as the duty cycle goes up. Table 2 shows the average reported kW impact based on 20 load control impact studies for programs based on the duty cycle used. These results support the oft-quoted rule-of-thumb that the load impact for 50% duty cycling is 1 kW per customer, which is the impact used in this analysis. However, many homes will experience an impact greater than I kW, especially newer homes.

Table D-2. Average Load Impacts by Cycling Strategy for AC DLC Programs

Cycling Strategy	Average Load Impact KW/Customer
33%	0.74
45%	0.81
50%	1.04
66%	*1.36*

Source: Summit Blue 2007b

Customer type also makes a difference. In a few cases where single-family and multi-family impacts were measured separately, multi-family impacts were 60% of single-family, and thus a 0.6kW load reduction is applied in this analysis for multi-family units (Summit Blue 2007b).

Eligible Residential Customers

All residential customers with central air-conditioning that live in areas that can receive control signals are considered eligible for the direct load control program. This includes single family and multi-family housing units. Residential accounts without central AC are assumed to have no participation. The ACEEE Reference Case reports that 51% of all housing units have CAC in Pennsylvania – both single family and multi-family.

Multi-family housing units often have building tenants which are not the account holders, therefore accounts are often aggregated into buildings. Some accounts have a master meter for the entire building, including tenants. Some accounts are for the “common” building loads (i.e., those loads that are part of a building account such as elevators, A/C (if applicable), lobby lighting, etc.), but individual tenants in these buildings have their own accounts. There, multi-family units often have fewer units with central AC than single family. However, in this analysis, due to data constraints, 51% was applied to both single and multi-family customers, and leads to a more conservative estimate of impacts.

Residential Participation Rates

Participation rates experienced in AC DLC programs vary across utilities typically from 7% of eligible customers to 40%, depending upon the effort made in maintaining and marketing the program (Summit Blue, 2007a). The utilities with the low levels of participation had essentially stopped marketing the program in recent years. Utilities with programs with sustained attention to customer retention or recruitment show higher participation rates than utilities with one-time or intermittent promotion. In Maryland, BG&E’s Demand Response Service program anticipates a residential participation rate of 50%, or approximately 450,000 controlled units (BGE, 2007). The pilot phase of this program was conducted from June 1 through September 30, 2007, and 58% received a “smart” load control switch, and 42% had a “smart” thermostat installed (BGE, 2007). One study examined 15 AC DLC programs nationwide and found an average of 24% participation for eligible customers (Summit Blue, 2008a).[12] For this analysis, 3 typical yet conservative scenarios were used: a low scenario of 15% for eligible customers; a medium scenario of 25%; and a high scenario of 35%.

Results

Table D.3 displays the input data and results. In summary, the results for residential programs reveal that a medium scenario reduction of 290 MW is possible by 2015 (with 174MW possible by the low scenario, and 406MW by the high). By 2020, 583 MW is achievable through the medium scenario (with 350MW possible by the low scenario, and 816MW by the high).

Table D-3. Potential Load Reduction from AC-DLC in Pennsylvania Residential Homes, in Years 2015 and 2020

INPUTS	**2015**	**2020**
Residential Peak Demand (MW)	16,398	17,398
Residential Customers: Total [a]	4,968,918	4,991,923
Single Family [a]	3,925,445	3,943,619
Multi-Family [a]	1,043,473	1,048,304
Eligible Residential Customers: Single Family [b,c]	51%	
Eligible Residential Customers: Multi-Family [b,d]	51%	
Load Reduction per AC-DLC per Single-Family Unit (kW)	1.0	
Load Reduction per AC-DLC per Multi-Family Unit (kW)	0.6	
DR Participation Rates of eligible customers:		
Low Scenario	25%	
Medium Scenario	25%	
High Scenario [c]	35%	
RESULTS	**2015**	**2020**
Residential Potential DR Load Reduction (MW):		
Low Scenario	174	350
Medium Scenario	290	583
High Scenario	406	816
Notes: *a.* Residential customers reflect number of housing units, as reported from Economy.com. *b.* Analysis assumes residences with central AC are eligible. Residential accounts without central AC are assumed to have no participation. Central AC percents obtained from ACEEE Reference Case. *c.* Higher participation than applied in the High Scenario is possible through design of program features, such as “opt-out” participation where participants are included in a program unless they chose to “opt-out”.		

Figure D-5 shows the resulting residential load shed reductions possible for Pennsylvania, from year 2010, when load reductions are expected to begin, through year 2025.

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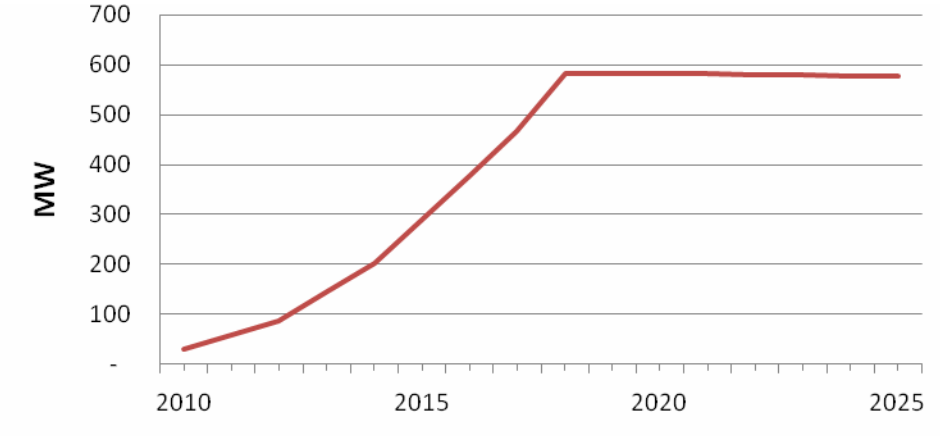
[12] Programs where participants are included in a program unless they chose to “opt-out” experience much higher participation rates. One utility is proposing a “hybrid” program for new construction, where existing customers must opt-in and new construction customers must opt-out. This program assumes that 70% of new construction customers will enroll in the initial years, and 80% in later years (Summit Blue, 2008b).

Figure D-5. Potential Residential Load Shed in Pennsylvania (Medium Scenario)



Room Air Conditioners

Other DR residential programs could involve tapping into the potential for callable load reductions from room air conditioners. At least one prominent DR provider is exploring the possibility of having manufacturers of room AC units embedding a home-area-network communication device into new units. This would enable cycling of room air conditioners without the need to install radio frequency load switches commonly used for residential direct load control applications. Callable load reductions from room air conditioners would provide a significant boost to load control capability and these reductions would be dispatchable in less than ten minutes. Some utilities are projecting to add a large number of new room air conditioners in the next five to ten years. The additional participation of a fraction of these room AC units could provide a substantial increase to the AC DLC program.

Other Appliances

Based on the experiences of other utilities, expanding the equipment controlled to other equipment beyond AC units can produce additional kW reductions. This could include electric hot water heaters and pool pumps. However, the saturation of electric hot water heaters is lower than for air conditioning, and control of hot water heaters generally produces only about one-third the load impact of air conditioners, especially in the summer when Pennsylvania utilities would most likely be calling DR events.

Commercial and Industrial DR Potential in Pennsylvania

Appropriate commercial sector DR programs will vary according to customer size and the type of facility. Direct load control of space conditioner equipment is a primary DR strategy intended for small commercial customers (e.g., under 100 kW peak load), although TOU rates combined with promising new thermal energy storage technologies could prove an effective combination. Mid-to-large commercial customers and smaller industrial customers could best be targeted for a curtailable load program requiring several hours of advanced notification or, where practical, for an Auto-DR program that can deliver load reductions with no more than ten minutes of advance notice. Thermal energy storage and other scheduled load control programs may also be applicable for some larger buildings or water pumping customers. In this assessment of DR potential, the focus is on the use of direct load control and curtailable load response programs. Studies have shown that pricing programs, specifically dispatchable pricing programs such as critical peak pricing (CPP) programs can provide similar impacts. These pricing programs are discussed in Section 3.2. However, for the purposes of this assessment, a focus on these load response programs is believed to be able to fully represent the DR potential, even though pricing programs could be used instead of these curtailable load programs with equal, or in some cases, greater efficiency.

The following DR program descriptions apply to both commercial and industrial customers:

- Small business direct load control (air conditioning)—Small commercial customers (under 100 kW peak load) account for a majority of customer accounts but typically only about one-quarter of total commercial load. Due to the nature of small businesses, particularly their small staffs for which energy management is a relatively low priority, it is not practical to rely on active customer response to load control events. Thus, small businesses may best be viewed in the same way as residential customers for purposes of DR.
- Curtailable load program—This program would be applicable to commercial and industrial customers willing to commit to self-activated load reductions of a minimum of perhaps 50 kW in response to a notice and request from a utility. The minimum curtailment threshold is designed to improve program cost-effectiveness by ensuring that recruitment and technical assistance costs are used for customers who can deliver significant load reductions. Advanced notice requirements would likely be two hours— long enough to allow customers an opportunity to prepare but short enough to maintain the DR resource as a viable resource that can be dispatched by operations staff. Enabling technologies would vary greatly, but utilities would educate customers about alternatives and could work with equipment vendors to facilitate equipment acquisition and installation. Incentives would be paid as capacity payment (in $/kW-month) or a discount on the customers' demand charges. Utilities could also offer a voluntary version of the program to attract greater participation. Customers would not commit to load reductions, but incentives would be lower and would be paid only on the reductions achieved during curtailment events.
- Automated demand response (Auto-DR)—This program would be marketed to facilities such as high-rise office buildings and large retail businesses that have energy management and control systems (EMCS) that monitor and control HVAC systems, lighting, and other building functions. The benefits of Auto-DR over curtailable load programs include customer loads curtailments with as little as ten minutes notice and greater assurance that customers will reduce loads by at least their contracted amount. Incentives would be paid as either capacity payments or demand charge discounts, but would be greater than for curtailable load program participants due to the additional technology investment that may be required and the allowance of curtailments on relatively short notice. UTILITIES would offer extensive technical assistance in setting up Auto-DR capability and would potentially provide financial assistance as well for customers making long-term commitments.
- Scheduled load control programs (including thermal energy storage)—Scheduled load control can help reduce utility peak demand, especially through shifting of space cooling loads enabled by thermal energy storage technologies. Large-customer TES systems could be promoted along with customer commitments to reduce operation of chillers or rooftop air conditioners during specified peak hours. Customers' return on investment can be increased by encouraging migration to a TOU rate, which would offer a rate discount for many of the hours that TES systems are recharging cooling capacity. Water pumping systems are typically good candidates for scheduled load control programs and utilities can investigate opportunities in the municipal water supply and irrigation sectors. Other, less traditional, opportunities may also be available, such as the leisure/resort industry's limiting recharging of electric golf carts to off-peak hours.
- Emergency under-frequency relay (program add-on)—Under-frequency relays (UFRs) automatically shut off electrical circuits in response to the circuits exceeding pre-set voltage thresholds specified by the utility. Use of UFRs is a valuable addition to a DR portfolio because the load response is both automatic and virtually instantaneous. UFRs can best be integrated into another DR program where participants are already engaging in load curtailment activities. It is expected that some customers who might consider participating in a DR program will not be willing to allow loads to be controlled via UFR since they would not receive any advanced notice. Incentives would also need to be greater to attract participants and provide acceptable compensation. However, the benefits of UFRs warrant their consideration as part of a utility's proposed DR portfolio.

Commercial DR Potential in Pennsylvania

To estimate potential load reductions for commercial units, a straight-forward approach of applying load shed participation rates and curtailment rates directly to commercial peak demand.

First, assumptions were made on the percentage of commercial customers who are willing to participate in DR programs. One study applied commercial participation rates ranging from 11% to 48% for commercial customers (Summit Blue, 2008a). Table D-4 displays participation rates for various types of commercial customers, disaggregated into two different peak demand categories (<300kW and >300kW).

Table D-4. Examples of Commercial Load Shed Participation Rates

	Peak Category	
Customer Segment	<300kW	>300kW
Office Buildings	11% - 15%	45% - 48%
Hospitals	13%	48%
Hotels	14%	45%
Educational Facilities	13%	43%
Retail	11%	42%
Supermarkets	12%	33%
Restaurants	11%	39%
Other Government Facilities	15%	44%
Entertainment	13%	41%

Source: Summit Blue 2008a

Because facility-specific data was not available for Pennsylvania, three conservative scenarios for participation rates were applied. A medium-scenario load participation rate of 20% was applied as it appears to be an average participation rate found by utilities with DR programs in place. A low scenario of 10% and a high scenario of 30% are applied.

Then, assumptions were made for curtailment rates, based on existing estimates of the fraction of load that has been shed by commercial customers enrolled in event-based DR programs callable by the utility. Table D-5 displays curtailment rates for various types of commercial customers, which range from 13% to 43%. For the purposes of this analysis, 3 conservative scenarios were applied: a low curtailment rate of 15%, a medium curtailment rate of 20%, and a high rate of 25%.

Table D-5. Examples of Commercial Curtailment Rates

Customer Segment	Average Curtailment Rate
Office Buildings	21%
Hospitals	18%
Hotels	15%
Educational Facilities	22%
Retail	18%
Supermarkets	13%
Restaurants	17%
Other Government Facilities	38%
Entertainment	43%

Source: Summit Blue 2008a

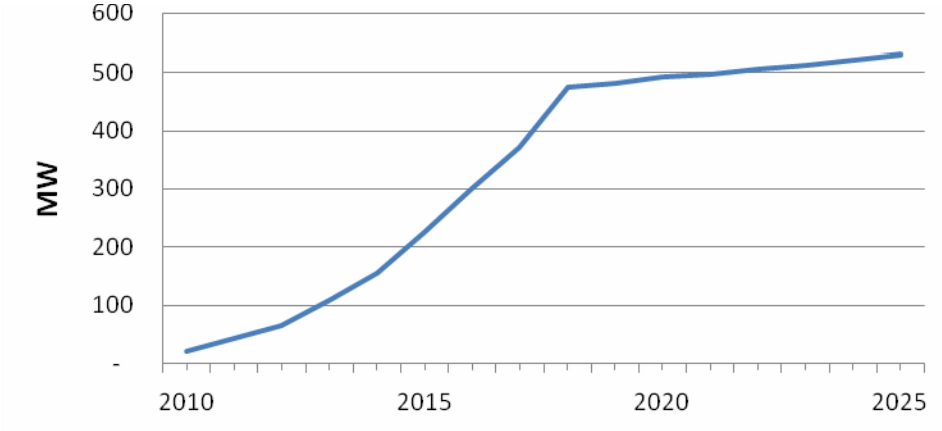
Table D-6 displays the input data and results. In summary, the commercial sector results reveal that a medium scenario reduction of 226 MW is possible by 2015 (with 85MW possible by the low scenario, and 425MW by the high). By 2020, 491 MW is achievable through the medium scenario (with 184MW possible by the low scenario, and 920MW by the high).

Table D-6. Potential Commercial Load Shed in Pennsylvania, in Years 2015 and 2020

INPUTS	2015	2020
Commercial Peak Demand (MW)	11,324	12,272
Load Shed Participation Rates:		
Low	10%	
Medium	20%	
High	30%	
Curtailment Rates:		
Low	15%	
Medium	20%	
High	25%	
RESULTS	2015	2020
Commercial DR load reductions (MW):		
Low	85	184
Medium	226	491
High	425	920

Figure D-6 shows the resulting commercial load shed reductions possible for Pennsylvania, from year 2010, when load reductions are expected to begin, through year 2025.

Figure D-6. Potential Commercial Load Shed in Pennsylvania (Medium Scenario)



DR programs that move towards the auto-DR concept can typically provide some load sheds that only require ten-minute notification or less. While some customer surveys have shown that most customers would prefer longer notification periods, many of these customers have not put in place the technologies to automate DR both load shed within a facility and the startup of emergency generation (ConEd, 2008). The value of DR and the design of DR programs should take into account system operations. Ten-minute notice DR can be valuable in helping defer some investment in T&D. While not all customers may choose to provide ten-minute notice response, there should be an increasing number of customers that will provide this type of response in the future and programs should be designed to acquire this resource. This type of DR is often a more valuable form of DR with higher savings for the utility, and utilities are often ready to pay up to twice as much to customers for this short-notice responsiveness.

Industrial DR Potential in Pennsylvania

A similar analysis was conducted for the industrial sector: load shed participation rates and curtailment rates were applied to industrial peak demand. A previous study found industrial participation rates to vary from 25% for facilities <300kW, to 50% for >300kW (Summit Blue, 2008a). For this study, the following rates were applied to participation: Low (20%); Medium (30%); and High (40%).

Previous studies have found industrial curtailment rates to vary from 17% (Quantec, 2007), to 30% (Consortium, 2004), to 75% (Nordham, 2007), resulting in a mean of 41%. The following conservative rates were applied to curtailment for this study: Low (20%); Medium (30%); and High (40%). With these participation rates and potential load curtailments, the high load reduction potential for the overall industrial sector loads is 16% (i.e., 40% participation and 40% of that load participating).

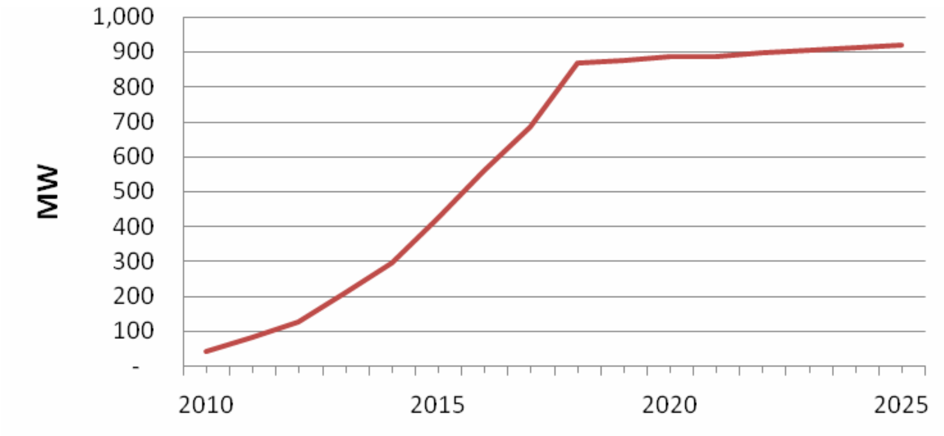
Table D-7 displays the input data and results. In summary, the industrial sector results reveal that a medium scenario reduction of 425MW is possible by 2015 (with 189MW possible by the low scenario, and 755MW by the high). By 2020, 887MW is achievable through the medium scenario (with 394MW possible by the low scenario, and 1,576MW by the high).

Table D-7. Potential Industrial Load Shed in Pennsylvania, in Years 2015 and 2020

INPUTS	2015	2020
Industrial Peak Demand (MW)	9,439	9,853
Load Participation Rates:		
Low	20%	
Medium	30%	
High	40%	
Curtailment Rates:		
Low	20%	
Medium	30%	
High	40%	
RESULTS	2015	2020
Industrial DR load reductions (MW):		
Low	189	394
Medium	425	887
High	755	1,576

Figure D-7 shows the resulting industrial load shed reductions possible for Pennsylvania, from year 2010, when load reductions are expected to begin, through year 2025.

Figure D-7. Potential Industrial Load Shed in Pennsylvania (Medium Scenario)



The largest load reductions, and often the most cost-effective, may be found in Pennsylvania's largest commercial and industrial customers. Data concerning these largest facilities were not available in Pennsylvania so estimates are not quantified separately from the industrial analysis given in the previous section.

Commercial and Industrial Backup Generation Potential in PA

Emergency backup generation is a prominent component of a callable load program strategy. Some of the emergency generators not currently participating in DR programs may not be permitted for use as a DR resource and regulations may further limit the availability of emergency generation for DR. In some cases, backup generators may not be equipped with the start-up equipment to allow the generator to participate in short-term notification programs. Utilities could consider a program to assist customers with equipment specification and set-up to promote DR program participation by backup generators.

In some instances, there may be environmental restrictions on emergency generation. Emissions of emergency generation may be regulated, and the future of such regulations may add some uncertainty. However, some areas have been able to have such restrictions lifted during system emergencies.

Two approaches can increase the amount of emergency generation in DR programs: 1) facilitating customer-owned generation, and 2) utility ownership of the generation, which is used to provide additional reliability for customers willing to locate the equipment at their facilities.

Customer-Owned Emergency Generation

To increase customer-owned emergency generation, utilities may assist customers with ownership of grid-synchronized emergency generation. Utilities may offer to pay for all equipment necessary for parallel interconnection with the utility grid, as well as all maintenance and fuel expenses. Once operational, the standby generators can be monitored and dispatched from a utility's control center, and they can also provide backup power during an outage. An additional benefit to the customer relative to typical backup generation is the seamless transition to and from the generator without the usual momentary power interruption.

Utility-Owned Emergency Generation

A second approach to increasing the availability of emergency generation for DR is by locating generation at customer sites that can be owned by a utility. Through this type of program, the customer receives emergency generation capability during system outages in exchange for paying a monthly fee consisting of both levelized capital costs and operation and maintenance costs.

Participants would likely receive capacity payments ($/kW-month) and/or energy payments ($/kWh) in exchange for granting a utility to dispatch the units for a limited number of events and total hours per year.

Backup Generation in Pennsylvania

PECO, the largest electricity provider in Pennsylvania, has seen an increase in customer-owned generation in recent years. PECO does not track this type of information or have any backup generation programs, but based on informal surveys, estimates at least 100 MW of customer-owned distributed generation is currently potentially callable in its service territory.

Total Pennsylvania back-up generation capacity for 2008 is estimated at approximately 2,655MW.[13] Additional analysis revealed that the commercial and industrial back-up capacity, each, is almost half of the total capacity, 1,307MW.[14] Assuming a medium scenario that 40% of the total backup in Pennsylvania is available for load shed, then 582MW of backup generation is available by 2015 and 1,238MW is available by 2020 (see Table D-8). The low scenario estimates a 436MW reduction by 2015 and a 928MW reduction by 2020. The high scenario estimates a 727MW reduction by 2015 and a 1,547MW reduction by 2020.

Table D-8. Potential Reductions from C&I Backup Generation in Pennsylvania, in Years 2015 and 2020

INPUTS	2015	2020
Total Backup Generation Capacity in PA (MW)	2,908	3,095
Backup Generation Potential (%):		
Low	30%	
Medium	40%	
High	50%	
RESULTS	2015	2020
Potential Reduction from C&I Backup Generation (MW):		
Low	436	928
Medium	582	1,238
High	727	1,547

Figure D-8 shows the resulting commercial and industrial backup generation reductions possible for Pennsylvania, from year 2010, when load reductions are expected to begin, through year 2025.

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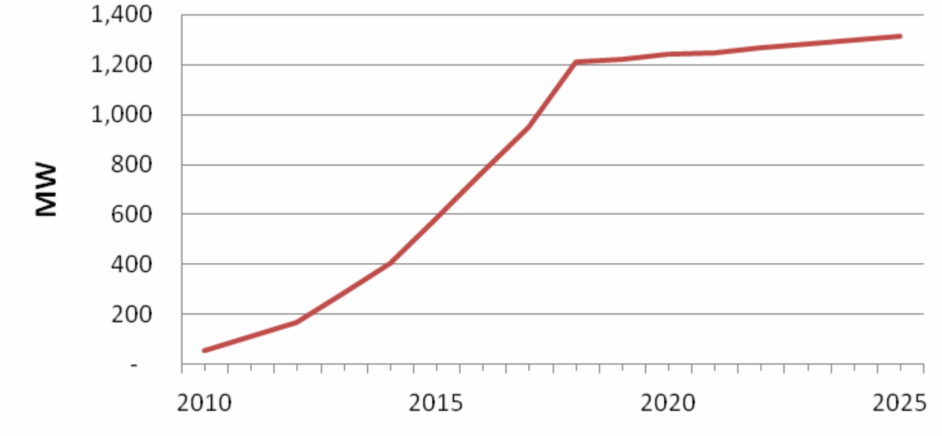
[13] Back-up generation capacity in Pennsylvania was estimated from form EIA-861 filings submitted by utilities nationwide (EIA, 2006). However, only utilities providing approximately one-quarter of total kWh report these numbers. It was assumed that the prevalence and usage of distributed generation in the remaining 75% of utilities is similar.

[14] The analysis first determined the back-up generator population nation-wide, and then scaled the data down to the New England region (CBECS resolution), accounting for proportional differences in building stock nation-wide and region-wide. The region-wide results were then scaled down to Pennsylvania specifically using the ratio of Pennsylvania population to regional population.

Figure D-8. Potential Reductions from C&I Backup Generation (Medium Scenario)



Pricing and Rates

In this assessment of DR potential, the focus is on the use of direct load control and curtailable load response programs callable by the utility. Studies have shown that pricing programs, specifically dispatchable pricing programs such as critical peak pricing (CPP) programs can provide similar impacts; however, for the purposes of this assessment, a focus on the these load response programs is believed to be able to fully represent the DR potential, even though pricing programs could be used instead of these curtailable load programs with equal, or in some cases, greater efficiency.

New rates may be introduced as part of a DR program, and may include real-time prices, or other time-differentiated rates, for commercial and industrial customers, and a modification of any existing residential time-of-use (TOU) rates. Any new rate structures would be designed to reduce system demand during peak periods and provide an opportunity for customers to reduce electric bills through load shifting.

Critical peak pricing (CPP) is a viable option for inclusion in a DR portfolio. In FERC's 2006 survey of utilities offering DR programs (citation below), roughly 25 entities reported offering at least one CPP tariff. However, many of the tariffs were pilot programs only, and almost all of the 11,000 participants were residential customers. The apparent lack of commercial CPP programs is supported by a 2006 survey of pricing and DR programs commissioned by the U.S. EPA (below), which found only four large-customer CPP programs, all of them in California. The pilot programs in California linked the CPP rate with "automated demand response" technologies that provide most of the impact. The CPP rate itself, and the price incentive that it creates, is not the driver behind the load reductions.

As stated, rate pricing options were not analyzed in this analysis. Event-based pricing programs achieve impacts very similar to the callable load programs presented above. Pilot studies and tariff evaluations of TOU-CPP programs[15] show the load reductions for called events are similar in magnitude to air conditioning DLC programs. This is not surprising in that most TOU-CPP participants use a programmable-automated thermostat to respond to CPP events in a manner similar to a DLC strategy. One difference is that the customer response is less under the control of the program or system operator that could change cycling strategies or thermostat set points across different events or different hours within an event. Similarly, demand-bid programs are simply calls for target load sheds, i.e., those bid into the program.

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[15] See Public Service Electric and Gas Company, "Evaluation of the MyPower Pricing Pilot Program," prepared by Summit Blue Consulting, 2007; and the California Energy Commission, "Impact evaluation of the California Statewide Pricing Pilot—Final Report," March 16, 2005. Web reference: http://www.energy.ca.gov/demandresponse/documents/index.html#group3.

In general, the direct load shed programs seem to provide greater MW of participation and more reliable reductions. However, the use of either TOU-CPP or a demand-bid program represents a point of view or policy position that price should be a centerpiece of the DR effort and help customers see prices in the electricity markets. From a point of view of simplicity and attaining firm capacity reductions, the direct load shed programs may offer some advantages. Ultimately, the choice between these direct load shed programs and pricing programs may come down to customer preferences and decisions by policy makers on the emphasis of DR efforts.

A time-differentiated rate is another option to consider that may not be "callable." Such rates include day-ahead real-time pricing (RTP), two-part RTP tariffs, and standard TOU rates. Although they are not "callable" in that the rate is generally in effect every day, there may be synergies between time-differentiated rates and callable load programs. In general, an RTP option will result in customers learning how to reduce energy consumption on essentially a daily basis when prices tend to be high (e.g., summer season afternoons and early evenings). Customers do not tend to track exact hourly prices, but they know when prices are likely to be higher (e.g., summer season afternoons with higher prices on hot days).[16] The benefits to the customer come from reducing consumption across many summer days when prices are high, rather than a focus on reduction during system event days. In general, the reductions on system peak days are roughly the same as on any summer day when prices are reasonably high. As a result, an RTP option can provide substantial benefits by increasing overall market and system efficiency through shifting loads from high priced periods to periods with lower prices. However, these tariffs may not provide the needed load relief on system-constrained event days.[17, 18]

Summary of DR Potential Estimates in Pennsylvania

Table D-9 shows the resulting load shed reductions possible for Pennsylvania, by sector, for years 2015, 2020, and 2025. Load impacts grow rapidly through 2018 as program implementation takes hold. After 2018, the program impacts increase at the same rate as the forecasted growth in peak demand.

The high scenario DR load potential reduction is within a range of reasonable outcomes in that it has an eleven year rollout period (beginning of 2010 through the end of 2020), providing a relatively long period of time to ramp up and integrate new technologies that support DR. A value nearer to the high scenario than the medium scenario would make a good MW target for a set of DR activities.

The high scenario results show a reduction in peak demand of 2,313MW is possible by 2015 (6.3% of peak demand); 4,860MW is possible by 2020 (13.2% of peak demand); and 5,077MW is possible by 2025 (13.8% of peak demand).

The more conservative medium scenario results show a reduction in peak demand of 1,523MW is possible by 2015 (4.1% of peak demand); 3,199MW is possible by 2020 (8.7% of peak demand); and 3,339MW is possible by 2025 (9.1% of peak demand).

These estimated reductions in peak demand are within a range to be expected for a population of Pennsylvania's size. Estimates of DR in other states show that the estimates calculated here for Pennsylvania are conservative: 15% reductions in peak demand in Florida are possible by 2023

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[16] See evaluations of the hourly pricing experiment offered by ComEd and the Chicago Energy Cooperative performed by Summit Blue Consulting (2003 through 2006).

[17] One way to make an RTP tariff more like an event-based DR program is to overlay a critical peak pricing (CPP) component on the RTP tariff where unusually high prices would be posted to customers with some notification period. Otherwise, it is unlikely that the high levels of reduction needed for system-event days would be attained.

[18] The complementary of event-based load shed programs with RTP tariffs is assessed in: Violette, D., R. Freeman, and C. Neil. "*DR Valuation and Market Analysis—Volume II: Assessing the DR Benefits and Costs*," Prepared for the International Energy Agency, TASK XIII, Demand-Side Programme, Demand Response Resources, January 6, 2006. Updated results are presented in: Violette, D. and R. Freeman; "*Integrating Demand Side Resource Evaluations in Resource Planning*;" Proceedings of the International Energy Program Evaluation Conference (IEPEC), Chicago, August 2007 (also at www.IEPEC.com).

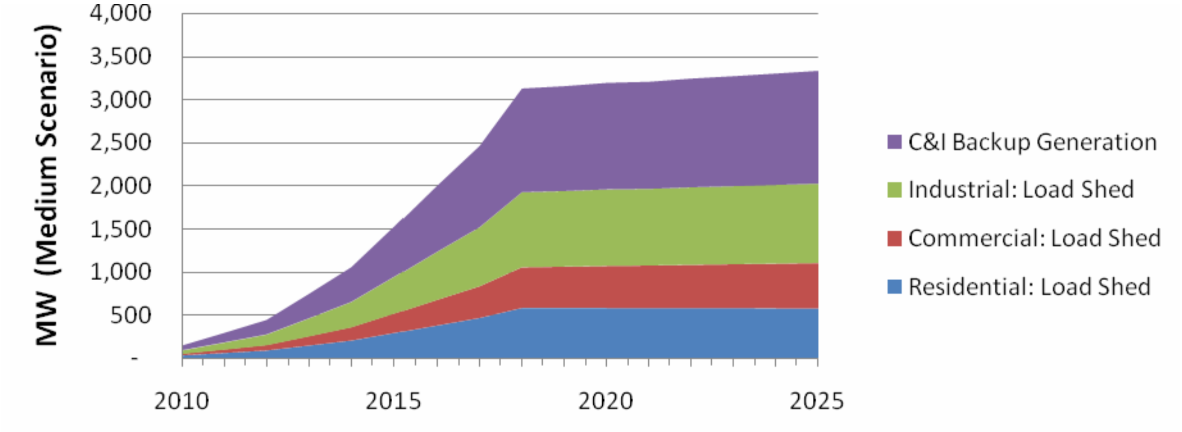
(Elliot et al., 2007a), and 13% are possible in Texas, also by year 2023 (Elliot et al., 2007b). DR potential for a utility in New York was estimated to be 9.3% of peak demand in 2017 (Summit Blue, 2008a). This finding is similar to that of a recent analysis estimating that peak load reductions from DR in the Northeast will be 8.2% of system peak load in 2020 and more than 11% by 2030 (EPRI and EEI, 2008). Estimation methods differ among the studies, but nonetheless show that the 9% reductions in Pennsylvania are realistic for the medium scenario by 2020, and the high scenario estimates for approximately 13% are achievable as well.

Table D-9. Summary of Potential DR in Pennsylvania, By Sector, for Years 2015, 2020, and 2025

	Low Scenario			Medium Scenario			High Scenario		
	2015	2020	2025	2015	2020	2025	2015	2020	2025
Load Sheds (MW):									
Residential	174	350	347	290	583	578	406	816	809
Commercial	85	184	198	226	491	529	425	920	992
Industrial	189	394	409	425	887	921	755	1,576	1,637
C&I Backup Generation (MW)	436	928	983	582	1,238	1,311	727	1,547	1,639
Total DR Potential (MW)	884	1,856	1,938	1,523	3,199	3,339	2,313	4,860	5,077
DR Potential as % of Total Peak Demand	2.4%	5.1%	5.3%	4.1%	8.7%	9.1%	6.3%	13.2%	13.8%

Figure D-9 shows the resulting load shed reductions possible for Pennsylvania, by sector, from year 2010, when load reductions are expected to begin, through year 2025.

Figure D-9. Potential DR Load Reductions in Pennsylvania by Sector (Medium Scenario)



These estimates reflect the level of effort put forth and utilities are recommended to set targets for the high scenarios. These estimates include assumptions based on utility experience regarding growth rates, participation rates, and program design, among others, and will adjust accordingly if differing assumptions are made. The assumptions made are believed to be conservative, and reflect minimum achievable DR potential. For example, participation rates for all of the sectors are based on experience in other states, and are based primarily on customer awareness, the ability to have automated response, and the adequacy of reward. If the statewide education program now required in Pennsylvania promotes DR programs and adequate incentives are offered, then participation rates higher than the medium scenario are entirely realistic.

Recommendations

This assessment indicates that the system peak demand can be reduced by approximately 8.7% or 3,199MW in 2020 in the medium case. In the high case, the reduction can be as high as 13.2% or 4,860MW. The high case is considered to be within a reasonable range if aggressive action begins by the end of 2009, providing for a twelve-year rollout of the DR efforts (at the beginning of 2010 through the end of 2020).

Pennsylvania House Bill 2200 requires electric distribution companies to reduce peak demand by 4.5% by May 31, 2013. This analysis estimates that 3.1% reductions in peak demand are possible by 2013 through DR policies alone. Energy efficiency reductions will provide further reductions, with opportunities to exceed the HB2200 goal.

Key recommendations include:

- It is important that the DR programs be integrated with the delivery of EE programs. Many gains in delivery efficiency are possible by combining and cross-marketing EE and DR programs. These can include new building codes and standards that include not only energy efficiency construction and equipment, but also the installation of addressable and dispatchable equipment. This can include addressable thermostats in new residences and the installation of addressable energy management systems in commercial and industrial buildings that can reduce loads in select end-uses across the building/facility. In addition, energy audits of residential or commercial facilities can also include an assessment of whether that facility is a good candidate for participation in a DR program through the identification of dispatchable loads. Furthermore, building commissioning and retro-commissioning EE programs that are becoming popular in many commercial and industrial sector programs have the energy management system as a core component of program delivery. At this time, the application of auto-DR can be assessed and marketed to the customer along with the EE savings from these site-commissioning programs.

- Additional programs that be considered for roll-out and can be designed within a 12-month period include:
  - Residential and small business AC direct load control using switches or thermostats (or giving customers their choice of technology).[19]
  - Aggressive enrollment of back-up generators in DR programs.

- Programs should be implemented which focus on achieving firm capacity reductions as this provides the highest value demand response. This is accomplished through establishing appropriate customer expectations and by conducting program tests for each DR program in each year. These tests should be used to establish expected DR program impacts when called and to work with customers each year to ensure that they can achieve the load reductions expected at each site.

- Customer education should be included in DR efforts. There is some perceived lack of customer awareness of programs and incentives. In addition, new programs will need marketing efforts as well as technical assistance to help customers identify where load reductions can be obtained and the technologies/actions needed to achieve these load reductions. Also, high-level education on the volatility of electricity markets helps customers understand why utilities and other entities are promoting DR and the customers' role in increasing demand response to help match up with supply-side resources to achieve lower cost resource solutions when markets become tight.

- Increase clarity and coordination between the Federal and State agencies and programs. While states have primary jurisdiction over retail demand response, the FERC has jurisdiction

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[19] This approach is currently being used successfully by LGE Energy.

over demand response in wholesale markets. Greater clarity and coordination between the Federal and State programs is needed.

- Pricing should form the cornerstone of an efficient electric market. Daily TOU pricing and day-ahead hourly pricing will increase overall market efficiency by causing shifts in energy use from on-peak to off-peak hours every day of the year. However, this does not diminish the need to have dispatchable DR programs that can address those few days that represent extreme events where the highest demands occur. These events are best addressed by dispatchable DR programs.

APPENDIX E – COMBINED HEAT AND POWER

Technical Potential for CHP

This section provides an estimate of the technical market potential for combined heat and power (CHP) in the industrial, commercial/institutional, and multi-family residential market sectors. Two different types of CHP markets were included in the evaluation of technical potential. Both of these markets were evaluated for high load factor (80% and above) and low load factor (51%) applications resulting in four distinct market segments that are analyzed.

Traditional CHP

Traditional CHP electrical output is produced to meet all or a portion of the base load for a facility and the thermal energy is used to provide steam or hot water. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often have “excess” thermal load compared to their on-site electric load. Commercial facilities almost always have excess electric load compared to their thermal load. Two sub-categories were considered:

High load factor applications: This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such colleges, hospitals, hotels, and prisons.

Low load factor applications: Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

Combined Cooling Heating and Power (CCHP)

All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration with the addition of a thermally activated cooling system. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round thermal load to support a traditional CHP system. A typical system would provide the annual hot water load, a portion of the space heating load in the winter months and a portion of the cooling load in during the summer months. Two sub-categories were considered:

Low load factor applications. These represent markets that otherwise could not support CHP due to a lack of thermal load.

Incremental high load factor applications: These markets represent round-the-clock commercial/institutional facilities that could support traditional CHP, but with cooling, incremental capacity could be added while maintaining a high level of utilization of the thermal energy from the CHP system. All of the market segments in this category are also included in the high load factor traditional market segment, so only the incremental capacity for these markets is added to the overall totals.

The estimation of technical market potential consists of the following elements:

- Identification of applications where CHP provides a reasonable fit to the electric and thermal needs of the user. Target applications were identified based on reviewing the electric and thermal energy consumption data for various building types and industrial facilities.
- Quantification of the number and size distribution of target applications. Several data sources were used to identify the number of applications by sector that meet the thermal and electric load requirements for CHP.
- Estimation of CHP potential in terms of megawatt (MW) capacity. Total CHP potential is then derived for each target application based on the number of target facilities in each size

category and sizing criteria appropriate for each sector.
- Subtraction of existing CHP from the identified sites to determine the remaining technical market potential.

The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and size distribution of the target CHP markets in the state. Identifying technical market potential is a preliminary step in the assessment of market penetration.

The basic approach to developing the technical potential is described below:

- *Identify existing CHP in the state.* The analysis of CHP potential starts with the identification of existing CHP. In Pennsylvania, there are 83 operating CHP plants totaling 2,704 MW of capacity. Of this existing CHP capacity, 55% of the sites and 77% of the capacity are in the industrial sector. This CHP electric capacity meeting onsite loads is deducted from any identified technical potential. A summary of the existing CHP capacity by industry is shown in Table E-1.
- *Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user*. Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the DOE EIA *Commercial Buildings Energy Consumption Survey (CBECS),* the DOE *Manufacturing Energy Consumption Survey (MECS)* and various market summaries developed by DOE, Gas Technology Institute (GRI), and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.
- *Quantify the number and size distribution of target applications*. Once applications that could technically support CHP were identified, the iMarket, Inc*. MarketPlace Database* and the *Major Industrial Plant Database* (MIPD) from IHI were utilized to identify potential CHP sites by SIC code or application, and location (county). The *MarketPlace Database* is based on the Dun and Bradstreet financial listings and includes information on economic activity (8 digit SIC), location (metropolitan area, county, electric utility service area, state) and size (employees) for commercial, institutional and industrial facilities. In addition, for select SICs limited energy consumption information (electric and gas consumption, electric and gas expenditures) is provided based on data from Wharton Econometric Forecasting (WEFA). MIPD has detailed energy and process data for 16,000 of the largest energy consuming industrial plants in the United States. The *MarketPlace Database* and MIPD were used to identify the number of facilities in target CHP applications and to group them into size categories based on average electric demand in kiloWatt-hours.
- *Estimate CHP potential in terms of MW capacity.* Total CHP potential was then derived for each target application based on the number of target facilities in each size category. It was assumed that the CHP system would be sized to meet the average site electric demand for the target applications unless thermal loads (heating and cooling) limited electric capacity. Tables E-2 through E-4 present the specific target market sectors, the number of potential sites and the potential MW contribution from CHP. There are two distinct applications and two levels of annual load making for four market segments in all. In traditional CHP, the thermal energy is recovered and used for heating, process steam, or hot water. In cooling CHP, the system provides both heating and cooling needs for the facility. High load factor applications operate at 80% load factor and above; low load factor applications operate at an assumed average of 4500 hours per year (51%) load factor. The high load factor cooling applications are also applications for traditional CHP, though the cooling applications have 25-30% more capacity than traditional. Therefore, the totals for the entire state, all four market segments, discounts these applications to avoid double counting.
- *Estimate the growth of new facilities in the target market sectors.* The technical potential

included economic projections for growth through 2025 by target market sectors in Pennsylvania. The growth factors used in the analysis for growth between the present and 2025 by individual sector are shown in Table E-5. These growth projections provided by ACEEE were used in this analysis as an estimate of the growth in new facilities. In cases where an economic sector is declining, it was assumed that no new facilities would be added to the technical potential for CHP. Based on these growth rates the total technical market potential is summarized in Table E-6.

Table E-1. Pennsylvania Existing CHP Facilities

SIC2	Industry Description	Sites	Capacity kW
20	Food	5	104,350
24	Lumber and Wood Products	3	15,652
26	Paper	8	412,180
28	Chemicals	11	329,160
29	Petroleum Refining	3	831,300
30	Rubber and Plastic	1	150
31	Leather	1	633
32	Slone, Clay, and Glass	1	250
33	Primary Metals	7	265,100
34	Fabricated Metals	1	900
35	Industrial Machinery	1	68,800
37	Transportation Equipment	3	40,676
39	Miscellaneous Manufacturing	1	1,800
40	Transportation	1	10,000
49	Utilities	2	14,180
70	Hotels, Lodging	10	450,729
65	Real Estate	4	4,040
79	Amusement and Recreation Services	2	513
80	Health Services	7	65,505
82	Educational Services	5	41,625
83	Social Services	1	200
87	Engineering Services	1	1,600
91	Government	3	881
92	Prison	1	44,500
	Total Existing CHP in Pennsylvania	83	2,704,724

Table E-2. Pennsylvania Technical Market Potential for CHP in Existing Facilities – Industrial Sector

SICs	Application	50-500 kW Sites	50-500 kW MW	500-1 MW Sites	500-1 MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
						Industrial (Traditional, High Load Factor							
20	Food	321	48.2	69	51.8	82	205.0	16	147.6	3	232.1	491	684.6
22	Textiles	120	13.5	36	20.3	19	35.6	7	66.9			182	136.3
23	Apparel and Textiles							1	4.8				
24	Lumber and Wood	251	7.5	72	10.8	16	8.0	2	17.6			341	43.9
25	Furniture	25	1.1	8	1.8	1	0.8	1	7.0			35	10.7
26	Paper	89	13.4	91	68.3	88	220.0	13	97.3	10	1,199.0	291	1,598.0
27	Printing/Publishing	138	20.7	14	10.5	5	12.5					157	43.7
28	Chemicals	174	26.1	109	81.8	140	350.0	17	175	7	364.5	447	997.0
29	Petroleum Refining	93	14.0	18	13.5	2	5.0			8	391.4	121	423.9
30	Rubber/Misc Plastics	226	10.2	189	42.5	126	94.5	2	15.1			543	162.3
32	Stone/Clay/Glass	7	1.1	9	6.8	1	2.5	3	22.9			20	33.2
33	Primary Metals	50	1.9	48	9.0	47	29.4	8	78.3	2	107.1	155	225.7
34	Fabricated Metals	170	7.7	44	9.9	21	15.8	6	47.9	1	37.9	242	119.1
35	Machinery/Computer Equip	13	0.5	1	0.2	4	2.5	4	29.5	1	100.9	23	133.6
36	Electronic Equipment							6	61.9				
37	Transportation Equip.	46	3.5	30	11.3	33	41.3	3	35.5	1	24.2	113	115.6
38	Instruments	17	1.3	3	1.1	2	2.5	2	12.2			24	17.1
39	Misc Manufacturing	41	1.5	11	2.1	3	1.9	1	4.7			56	10.2
	Total Industrial	1781	171.9	752	341.4	590	1,027.1	92	824.1	33	2,457.3	3241	4,755.0

Table E-3. Pennsylvania Technical Market Potential for CHP in Existing Facilities – Commercial, Traditional CHP

SICs	Application	50-500 kW Sites	50-500 kW MW	500-1 MW Sites	500-1 MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
Commercial/Institutional (Traditional, High Load Factor)													
6513	Apartments	408	30.6	149	55.9	22	27.5					579	114.0
4222, 5142	Warehouses	28	4.2	22	16.5	4	10.0					54	30.7
4941, 4952	Water Treatment/Sanitary	172	25.8	69	51.8	59	147.5					300	225.1
7011, 7041	Hotels	748	84.2	229	128.8	86	161.3	3	28.1			1066	402.3
8051, 8052, 8059	Nursing Homes	473	71.0	362	271.5	77	192.5					912	535.0
8062, 8063, 8069	Hospitals	117	17.6	83	62.3	192	480.0	3	37.5			395	597.3
8221, 8222	Colleges/Universities	106	15.9	117	87.8	69	172.5	46	575.0	9	225.0	347	1,076.2
9223, 9211 (Courts), 9224 (firehouses)	Prisons	23	3.5	20	15.0	45	112.5	7	87.5			95	218.5
	C/I High LF Total	2075	252.6	1051	689.4	554	1,303.8	59	728.1	9	225.0	3748	3,198.9
Commercial/Institutional (Traditional, Low Load Factor)													
7542	Carwashes	75	11.3									75	11.3
8412	Museums	85	12.8	4	3.0	1	2.5					90	18.3
7211, 7213, 7218	Laundries	50	7.5	5	3.8							55	11.3
7991, 00, 01	Health Clubs	181	27.2	30	22.5							211	49.7
7992, 7997-9904, 7997-9906	Golf/Country Clubs	347	52.1	26	19.5							373	71.6
8211, 8243, 8249, 8299	Schools	1733	65.0	343	64.3	41	25.6	5	15.6			2122	170.6
	C/I High LF Total	2471	175.7	408	113.1	42	28.1	5	15.6			2926	332.5
	C/I Traditional Total	4546	428.3	1459	802.5	596	1,331.9	64	743.8	9	225.0	6674	3,531.4

Table E-4. Pennsylvania Technical Market Potential for CHP in Existing Facilities – Commercial, Cooling

SICs	Application	50-500 kW Sites	50-500 kW MW	500-1 MW Sites	500-1 MW (MW)	1-5 MW Sites	1-5 MW (MW)	5-20 MW Sites	5-20 MW (MW)	>20 MW Sites	>20 MW (MW)	Total Sites	Total MW
Commercial Cooling, High Load Factor													
7011, 7041	Hotels- Cooling	748	112.2	229	171.8	86	215.0	3	37.5			1066	536.5
8051, 8052, 8059	Nursing Homes- Cooling	473	85.1	362	325.8	77	231.0					912	641.9
8062, 8063, 8069	Hospitals- Cooling	118	21.2	84	75.6	196	588.0	3	45.0			401	729.8
	C/I Cooling High LF	1339	218.6	675	573.15	359	1034	6	82.5			2379	1908.2
Commercial Cooling, Low Load Factor													
43	Post Offices	155	23.3	2	1.5							157	24.8
4581	Airports	13	2.0									13	2.0
6512	Office Buildings - Cooling	2273	170.5	1135	425.6	454	567.5					3862	1,163.6
7832	Movie Theaters	71	10.7									71	10.7
52,53,56,57	Big Box Retail	1184	177.6	323	242.3	98	245.0					1605	664.9
5411, 5421, 5451, 5461, 5499	Food Sales	1759	131.9	274	102.8	51	63.8					2084	298.4
5812, 00, 01, 03, 05, 07, 08	Restaurants	2231	167.3	25	9.4							2256	176.7
	Total Cooling Low LF	7686	683.2	1759	781.5	603	876.25					10048	2340.93
	Total Cooling	9025	901.8	2434	1354.7	962	1910.25	6	82.5			12427	4249.2
	Total C/I All Types	12232	1177.0	3218	1755.9	1199	2518.3	64	768.5	9	225.0	16722	6444.8

Note: High Load factor cooling adds only 30% to the total C/I MW potential because the sites are already included in High LF Traditional. The 30% represents the incremental capacity offered by adding cooling.

Table E-5. Pennsylvania Sector Growth Projections Through 2025

SIC Code	Market Sector	2008-2025 Real Growth
20	Food	5.7%
22	Textiles	0.3%
24	Lumber and Wood	16.0%
25	Furniture	16.0%
26	Paper	16.0%
27	Printing/Publishing	0.3%
28	Chemicals	47.2%
29	Petroleum Refining	47.2%
30	Rubber/Misc Plastics	47.2%
32	Stone/Clay/Glass	29.9%
33	Primary Metals	22.2%
34	Fabricated Metals	22.2%
35	Machinery/Computer Equip	51.5%
37	Transportation Equip.	44.4%
38	Instruments	33.7%
39	Misc Manufacturing	16.0%
43	Post Offices	16.5%
4581	Airports	16.5%
6512	Office Buildings - Cooling	0.0%
6513	Apartments	0.0%
7542	Carwashes	0.0%
7832	Movie Theaters	29.3%
8412	Museums	29.3%
4222, 5142	Warehouses	75.4%
4941, 4952	Water Treatment/Sanitary	18.5%
52,53,56,57	Big Box Retail	67.2%
5411, 5421, 5451, 5461, 5499	Food Sales	67.2%
5812, 00, 01, 03, 05, 07, 08	Restaurants	29.3%
7011, 7041	Hotels	29.3%
7011, 7041	Hotels- Cooling	29.3%
7211, 7213, 7218	Laundries	0.0%
7991, 00, 01	Health Clubs	29.3%
7992, 7997-9904, 7997-9906	Golf/Country Clubs	29.3%
8051, 8052, 8059	Nursing Homes	8.0%
8051, 8052, 8059	Nursing Homes- Cooling	8.0%
8062, 8063, 8069	Hospitals	8.0%
8062, 8063, 8069	Hospitals- Cooling	8.0%
8211, 8243, 8249, 8299	Schools	8.0%
8221, 8222	Colleges/Universities	8.0%
9223, 9211 (Courts), 9224 (firehouses)	Prisons	7.7%

Table E-6. CHP Market Segments, Pennsylvania Existing Facilities and Expected Growth 2008-2025

Market	50-500 kW MW	500-1 MW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total MW
Traditional High Load Factor Market						
Existing Facilities	425	1,031	2,331	1,552	2,682	8,021
New Facilities	76	188	449	370	814	1,896
Total	500	1,219	2,780	1,922	3,496	9,917
Traditional Low Load Factor Market						
Existing Facilities	176	113	28	16	0	333
New Facilities	32	19	2	0	0	53
Total	208	132	30	16	0	385
Cooling CHP High Load Factor Market (partially additive)						
Existing Facilities	219	573	1,034	83	0	1,908
New Facilities	41	83	129	13	0	265
Total	260	656	1,163	95	0	2,173
Cooling CHP Low Load Factor Market						
Existing Facilities	683	782	876	0	0	2,341
New Facilities	265	234	208	0	0	706
Total	948	1,016	1,084	0	0	3,047
Total Market including Incremental Cooling Load						
Existing Facilities	1,349	2,097	3,545	1,593	2,682	11,267
New Facilities	385	466	697	373	814	2,735
Total	1,734	2,563	4,242	1,966	3,496	14,002

Note: High load factor cooling market is comprised of a portion of the traditional high load factor market that has both heating and cooling loads. The total high load factor cooling market is shown, but only 30% of it is incremental to the portion already counted in the traditional high load factor market. Growth rates were extrapolated for the 2020-2025 market penetration forecast.

Energy Price Projections

The expected future relationship between purchased natural gas and electricity prices, called the *spark spread* in this context, is one major determinant of the ability of a facility with electric and thermal energy requirements to cost-effectively utilize CHP. For this screening analysis, a fairly simple methodology was used:

Electric Price Estimation

- Retail electric price forecasts EIA's Annual Energy Forecast for 2007 were used as the starting point for the analysis. ACEEE provided state by state estimates. The annual price forecasts provided were converted to 5 year averages for use in the market penetration model. These prices are shown in Table E-7.
- The electricity price assumptions for the high load factor CHP applications were as follows

  - 50-500 kW – Commercial average price
  - 500 kW to 5 MW – Industrial average price
  - 5 MW and above – 90% of industrial average price
- Price adjustments for customer load factor were defined as follows:
  - High load factor – 100% of the estimated value
  - Low load factor – 120% of the estimated value
  - Peak cooling load – 150% of the estimated value
- For a customer generating a portion of his own power with CHP, standby charges are estimated at 15% of the defined average electric rate. Therefore, when considering CHP, only 85% of a customer's rate can be avoided.

Natural Gas Price Estimation

- The natural gas price assumptions are based on the industrial retail price shown in the table.
  - All customer boiler fuel is assumed at the industrial rate except for the CHP market below 500 kW where the boiler gas price is assumed to be $0.50/MMBtu higher
  - All CHP fuel is assumed to be at a $0.60/MMBt discount to the retail industrial price.

Table E-7. Input Price Forecast (EIA-AEO 2007) and Pennsylvania Industrial Electric Price Estimation

Pennsylvania Energy Prices	Avg. 2007-2009	Avg. 2010-2014	Avg. 2015-2019	Avg. 2020-2024
Pennsylvania Retail Electricity Prices (2006$/kWh)				
Residential	$0.110	$0.124	$0.125	$0.132
Commercial	$0.0901	$0.101	$0.107	$0.114
Industrial	$0.067	$0.076	$0.079	$0.086
Pennsylvania Retail Natural Gas Prices (2006$/MMbtu)				
Residential	$15.695	$14.325	$14.612	$15.161
Commercial	$13.525	$11.936	$12.069	$12.475
Industrial	$11.466	$9.591	$9.765	$10.245

CHP Technology Cost and Performance

The CHP system itself is the engine that drives the economic savings. The cost and performance characteristics of CHP systems determine the economics of meeting the site's electric and thermal loads. A representative sample of commercially and emerging CHP systems was selected to profile performance and cost characteristics in combined heat and power (CHP) applications. The selected systems range in capacity from approximately 100 – 20,000 kW. The technologies include gas-fired reciprocating engines, gas turbines, microturbines and fuel cells. The appropriate technologies were allowed to compete for market share in the penetration model. In the smaller market sizes, reciprocating engines competed with microturbines and fuel cells. In intermediate sizes (1 to 20 MW), reciprocating engines competed with gas turbines.

Cost and performance estimates for the CHP systems were based on work being undertaken for the EPA.[20] The foundation for these updates is based on work previously conducted for NYSERDA[21], on peer-reviewed technology characterizations that Energy and Environmental Analysis (EEA) developed for the National Renewable Energy Laboratory[22] and on follow-on work conducted by DE

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[20] EPA CHP Partnership Program, Technology Characterizations, December 2007 (under review).

[21] *Combined Heat and Power Potential for New York State*, Energy Nexus Group (later became part of EEA), for NYSERDA, May 2002.

[22] "Gas-Fired Distributed Energy Resource Technology Characterizations", NREL, November 2003, http://www.osti.gov/bridge

Solutions for Oak Ridge National Laboratory.[23] Additional emissions characteristics and cost and performance estimates for emissions control technologies were based on ongoing work EEA is conducting for EPRI.[24] Data is presented for a range of sizes that include basic electrical performance characteristics, CHP performance characteristics (power to heat ratio), equipment cost estimates, maintenance cost estimates, emission profiles with and without after-treatment control, and emissions control cost estimates. The technology characteristics are presented for three years: 2005, 2010, 2020. The 2007-2010 estimates are based on current commercially available and emerging technologies. The cost and performance estimates for 2010-2015 and 2015-2020 reflect current technology development paths and currently planned government and industry funding. These projections were based on estimates included in the three references mentioned above. NOx, CO and VOC emissions estimates in lb/MWh are presented for each technology both with and without aftertreatment control (AT). For this analysis, aftertreatment was only included for the 800 kW and 3000 kW engines. The installed costs in Tables E8 through E11 are based on typical national averages.

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[23] "Clean Distributed Generation Performance and Cost Analysis", DE Solutions for ORNL. April 2004.

[24] "Assessment of Emerging Low-Emissions Technologies for Distributed Resource Generators", EPRI, January 2005.

Table E-8. Reciprocating Engine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
100 kW	Installed Costs, $/kW	$2,210	$1,925	$1,568
	Heat Rate, Btu/kWh	12,000	10,830	10,500
	Electric Efficiency, %	28.4%	31.5%	32.5%
	Thermal Output, Btu/kWh	6100	5093	4874
	O&M Costs, $/kWh	0.022	0.013	0.012
	NOx Emissions, lbs/MWh (w/ AT)	0.10	0.15	0.15
	CO Emissions w/AT, lb/MWh	0.32	0.60	0.30
	VOC Emissions w/AT, lb/MWh	0.10	0.09	0.05
	PMT 10 Emissions, lb/MWh	0.11	0.11	0.11
	SO2 Emissions, lb/MWh	0.0068	0.0064	0.0062
	After-treatment Cost, $/kW	incl.	incl.	incl.
800 kW	Installed Costs, $/kW	$1,640	$1,443	$1,246
	Heat Rate, Btu/kWh	9,760	9,750	9,225
	Electric Efficiency, %	35.0%	35.0%	37.0%
	Thermal Output, Btu/kWh	2313	3791	3250
	O&M Costs, $/kWh	0.013	0.01	0.009
	NOx Emissions, lbs/MWh (w/ AT)	0.5	1.24	0.93
	CO Emissions w/AT, lb/MWh	1.87	0.45	0.31
	VOC Emissions w/AT, lb/MWh	0.47	0.05	0.05
	PMT 10 Emissions, lb/MWh	0.10	0.01	0.01
	SO2 Emissions, lb/MWh	0.0068	0.0057	0.0054
	After-treatment Cost, $/kW	300	190	140
3000 kW	Installed Costs, $/kW	$1,130	$1,100	$1,041
	Heat Rate, Btu/kWh	9,492	8,750	8,325
	Electric Efficiency, %	35.9%	39.0%	41.0%
	Thermal Output, Btu/kWh	3510	3189	2982
	O&M Costs, $/kWh	0.011	0.0083	0.008
	NOx Emissions, lbs/MWh (w/ AT)	1.52	1.24	0.775
	CO Emissions w/AT, lb/MWh	0.78	0.31	0.31
	VOC Emissions w/AT, lb/MWh	0.34	0.10	0.10
	PMT 10 Emissions, lb/MWh	0.01	0.01	0.01
	SO2 Emissions, lb/MWh	0.0057	0.0051	0.0049
	After-treatment Cost, $/kW	200	130	100
5000 kW	Installed Costs, $/kW	$1,130	$1,099	$1,038
	Heat Rate, Btu/kWh	8,758	8,325	7,935
	Electric Efficiency, %	39.0%	41.0%	43.0%
	Thermal Output, Btu/kWh	3046	2797	2605
	O&M Costs, $/kWh	0.009	0.008	0.008
	NOx Emissions, lbs/MWh (w/ AT)	1.55	1.24	0.775
	CO Emissions w/AT, lb/MWh	0.75	0.31	0.31
	VOC Emissions w/AT, lb/MWh	0.22	0.10	0.10
	PMT 10 Emissions, lb/MWh	0.01	0.01	0.01
	SO2 Emissions, lb/MWh	0.0054	0.0049	0.0047
	After-treatment Cost, $/kW	150	115	80

Table E-9. Microturbine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
60 kW	Installed Costs, $/kW	$2,739	$2,037	$1,743
	Heat Rate, Btu/kWh	13,891	12,500	11,375
	Electric Efficiency, %	24.6%	27.3%	30.0%
	Thermal Output, Btu/kWh	6308	3791	3102
	O&M Costs, $/kWh	0.022	0.016	0.012
	NOx Emissions, lbs/MWh (w/ AT)	0.15	0.14	0.13
	CO Emissions w/AT, lb/MWh	0.24	0.22	0.20
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.22	0.20	0.19
	SO2 Emissions, lb/MWh	0.0079	0.0074	0.0067
	After-treatment Cost, $/kW			
250 KW	Installed Costs, $/kW	$2,684	$2,147	$1,610
	Heat Rate, Btu/kWh	13,080	11,750	10,825
	Electric Efficiency, %	2.6%	29.0%	31.5%
	Thermal Output, Btu/kWh	4800	3412	2625
	O&M Costs, $/kWh	0.015	0.013	0.012
	NOx Emissions, lbs/MWh (w/ AT)	0.43	0.24	0.13
	CO Emissions w/AT, lb/MWh	0.26	0.26	0.24
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.18	0.18	0.16
	SO2 Emissions, lb/MWh	0.0070	0.0069	0.0064
	After-treatment Cost, $/kW	500	200	90

Table E-10. Fuel Cell Cost and Performance Characteristics

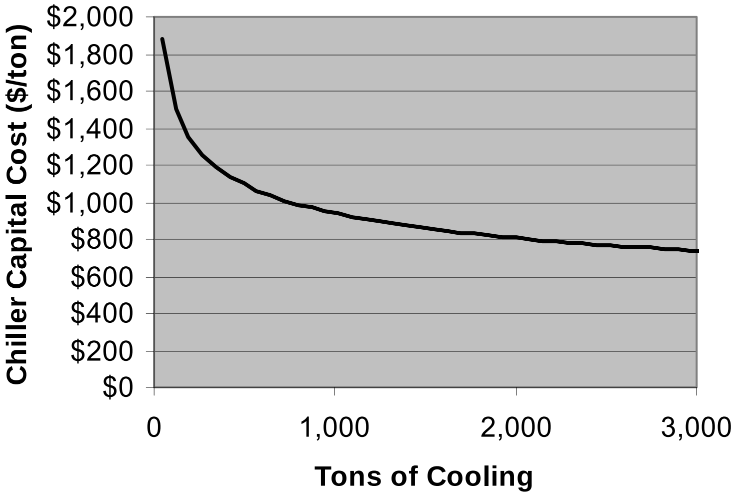
CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
200 kW PAFC in 2005 150 kW PEMFC in outyears	Installed Costs, $/kW	$6,310	$4,782	$3,587
	Heat Rate, Btu/kWh	9,480	9,480	8,980
	Electric Efficiency, %	36.0%	36.0%	38.0%
	Thermal Output, Btu/kWh	4250	3482	3281
	O&M Costs, $/kWh	0.038	0.017	0.015
	NOx Emissions, lbs/MWh (w/ AT)	0.06	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.07	0.07	0.07
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO2 Emissions, lb/MWh	0.0057	0.0056	0.0053
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.
300 kW MCFC	Installed Costs, $/kW	$5,580	$4,699	$3,671
	Heat Rate, Btu/kWh	8,022	7,125	6,920
	Electric Efficiency, %	42.5%	47.9%	49.3%
	Thermal Output, Btu/kWh	1600	1723	1602
	O&M Costs, $/kWh	0.035	0.02	0.015
	NOx Emissions, lbs/MWh (w/ AT)	0.1	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.07	0.05	0.04
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO2 Emissions, lb/MWh	0.0057	0.0042	0.0041
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.
1200 kW MCFC	Installed Costs, $/kW	$5,250	$4,523	$3,554
	Heat Rate, Btu/kWh	8,022	7,110	6,820
	Electric Efficiency, %	42.5%	48.0%	50.0%
	Thermal Output, Btu/kWh	1583	1706	1503
	O&M Costs, $/kWh	0.032	0.019	0.015
	NOx Emissions, lbs/MWh (w/ AT)	0.05	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.04	0.04	0.03
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO2 Emissions, lb/MWh	0.0044	0.0042	0.0040
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.

Table E-11. Gas Turbine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
3000 KW GT	Installed Costs, $/kW	$1,690	$1,560	$1,300
	Heat Rate, Btu/kWh	13,100	12,650	11,200
	Electric Efficiency, %	26.0%	27.0%	30.5%
	Thermal Output, Btu/kWh	5018	4489	4062
	O&M Costs, $/kWh	0.0074	0.0065	0.006
	NOx Emissions, lbs/MWh (w/ AT)	0.68	0.38	0.2
	CO Emissions w/AT, lb/MWh	0.55	0.53	0.47
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.21	0.20	0.18
	SO2 Emissions, lb/MWh	0.0070	0.0069	0.0069
	After-treatment Cost, $/kW	210	175	150
10 MW GT	Installed Costs, $/kW	$1,298	$1,342	$1,200
	Heat Rate, Btu/kWh	11,765	10,800	9,950
	Electric Efficiency, %	29.0%	31.6%	34.3%
	Thermal Output, Btu/kWh	4674	4062	3630
	O&M Costs, $/kWh	0.007	0.006	0.005
	NOx Emissions, lbs/MWh (w/ AT)	0.67	0.37	0.2
	CO Emissions w/AT, lb/MWh	0.50	0.46	0.42
	VOC Emissions w/AT, lb/MWh	0.02	0.02	0.02
	PMT 10 Emissions, lb/MWh	0.20	0.18	0.17
	SO2 Emissions, lb/MWh	0.0069	0.0064	0.0059
	After-treatment Cost, $/kW	140	125	100
40 MW GT	Installed Costs, $/kW	$972	$944	$916
	Heat Rate, Btu/kWh	9,220	8,865	8,595
	Electric Efficiency, %	37.0%	38.5%	39.7%
	Thermal Output, Btu/kWh	3189	3019	2892
	O&M Costs, $/kWh	0.004	0.004	0.004
	NOx Emissions, lbs/MWh (w/ AT)	0.55	0.2	0.1
	CO Emissions w/AT, lb/MWh	0.04	0.04	0.04
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.16	0.15	0.15
	SO2 Emissions, lb/MWh	0.0054	0.0052	0.0051
	After-treatment Cost, $/kW	90	75	40

In the cooling markets, an additional cost was added to reflect the costs of adding chiller capacity to the CHP system. These costs depend on the sizing of the absorption chiller which in turn depends on the amount of usable waste heat that the CHP system produces. Figure E-1 shows this cost approximation.

Figure E-1. Absorption Chiller Capital Costs



Market Penetration Analysis

EEA has developed a CHP market penetration model that estimates cumulative CHP market penetration in 5-yrar increments. For this analysis, the forecast periods are 2012, 2017, and 2022. These results are interpolated to the output years 2010, 2015, 2020, and 2025. The target market is comprised of the facilities that make up the technical market potential as defined in previously in this section. Thee economic competition module in the market penetration model compares CHP technologies to purchased fuel and power in 5 different sizes and 4 different CHP application types. The calculated payback determines the potential pool of customers that would consider accepting the CHP investment as economic. Additional, non economic screening factors are applied that limit the pool of customers that can accept CHP in any given market/size. Based on this calculated economic potential, a market diffusion model is used to determine the cumulative market penetration for each 5-year time period. The cumulative market penetration, economic potential and technical potential are defined as follows:

- *Technical potential* represents the total capacity potential from existing and new facilities that are likely to have the appropriate physical electric and thermal load characteristics that would support a CHP system with high levels of thermal utilization during business operating hours.
- *Economic potential*, as shown in the table, reflects the share of the technical potential capacity (and associated number of customers) that would consider the CHP investment economically acceptable according to a procedure that is described in more detail below.
- *Cumulative market penetration* represents an estimate of CHP capacity that will actually enter the market between 2008 and 2025. This value discounts the economic potential to reflect non-economic screening factors and the rate that CHP is likely to actually enter the market.

In addition to segmenting the market by size, as shown in the table, the analysis is conducted in four separate CHP market applications (high load and low load factor traditional CHP and high and low load factor CHP with cooling.) These markets are considered individually because both the annual load factor and the installation and operation of thermally activated cooling has an impact on the system economics.

Economic potential is determined by an evaluation of the competitiveness of CHP versus purchased fuel and electricity. The projected future fuel and electricity prices and the cost and performance of CHP technologies determine the economic competitiveness of CHP in each market. CHP technology and performance assumptions appropriate to each size category and region were selected to represent the competition in that size range (Table E-12). Additional assumptions were made for the competitive analysis. Technologies below 1 MW in electrical capacity are assumed to have an economic life of 10 years. Larger systems are assumed to have an economic life of 15 years. Capital related amortization costs were based on a 10% discount rate. Based on their operating characteristics (each category and each size bin within the category have specific assumptions about the annual hours of CHP operation (80-90% for the high load factor cases with appropriate adjustments for low load factor facilities), the share of recoverable thermal energy that gets utilized (80%-90%), and the share of useful thermal energy that is used for cooling compared to traditional heating. The economic figure-of-merit chosen to reflect this competition in the market penetration model is simple payback.[25] While not the most sophisticated measure of a project's performance, it is nevertheless widely understood by all classes of customers.

Table E-12. Technology Competition Assumed within Each Size Category

Market Size Bins	*Competing Technologies*
50 - 500 kW	100 kW Recip Engine
	70 kW Microturbine
	150 kW PEM Fuel Cell
500 - 1,000 kW	300 kW Recip Engine (multiple units)
	70 kW Microturbine (multiple units)
	250 kW MC/SO Fuel Cell (multiple units)
1 - 5 MW	3 MW Recip Engine
	3 MW Gas Turbine
	2 MW MC Fuel Cell
5 - 20 MW	5 MW Recip Engine
	5 MW Gas Turbine
20 - 100 MW	40 MW Gas Turbine

Rather than use a single payback value, such as 3-years or 5-years as the determinant of economic potential, we have based the market acceptance rate on a survey of commercial and industrial facility operators concerning the payback required for them to consider installing CHP. Figure E-2 shows the percentage of survey respondents that would accept CHP investments at different payback levels[26]. As can be seen from the figure, more than 30% of customers would reject a project that promised to return their initial investment in just one year. A little more than half would reject a project with a payback of 2 years. This type of payback translates into a project with an ROI of between 49-100%. Potential explanations for rejecting a project with such high returns is that the average customer does not believe that the results are real and is protecting himself from this perceived risk by requiring very high projected returns before a project would be accepted, or that the facility is very capital limited and is rationing its capital raising capability for higher priority projects (market expansion, product improvement, etc.).

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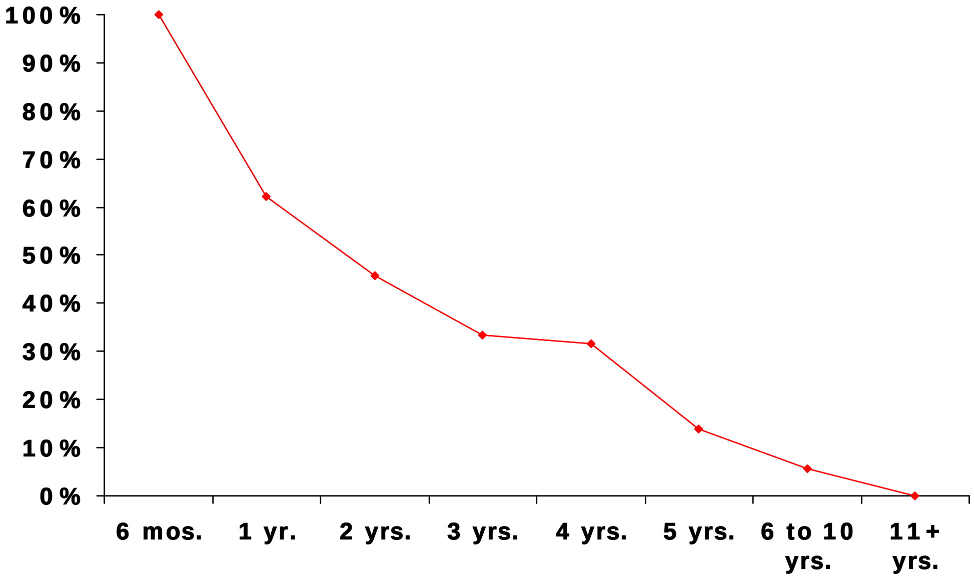
[25] Simple payback is the number of years that it takes for the annual operating savings to repay the initial capital investment.

[26] "Assessment of California CHP Market and Policy Options for Increased Penetration", California Energy Commission, July, 2005.

Figure E-2. Customer Payback Acceptance Curve



Source: *Primen's 2003 Distributed Energy Market Survey*

For each market segment, the economic potential represents the technical potential multiplied by the share of customers that would accept the payback calculated in the economic competition module.

The estimation of market penetration includes both a non-economic screening factor and a factor that estimates the rate of market penetration (diffusion.) The non-economic screening factor was applied to reflect the share of each market size category (i.e., applications of 50 to 500 kW, applications of 500 to 1,000 kW, etc) within the economic potential that would be willing and able to consider CHP at all. These factors range from 32% in the smallest size bin (50-500 kW) to 64% in the largest size bin (more than 20 MW.) These factors are intended to take the place of a much more detailed screening that would eliminate customers that do not actually have appropriate electric and thermal loads in spite of being within the target markets, do not use gas or have access to gas, do not have the space to install a system, do not have the capital or credit worthiness to consider investment, or are otherwise unaware, indifferent, or hostile to the idea of adding CHP. The specific value for each size bin was established based on an evaluation of EIA facility survey data and gas use statistics from the iMarket database.

The rate of market penetration is based on a *Bass diffusion curve* with allowance for growth in the maximum market. This function determines cumulative market penetration for each 5-year period. Smaller size systems are assumed to take a longer time to reach maximum market penetration than larger systems. Cumulative market penetration using a Bass diffusion curve takes a typical S-shaped curve. In the generalized form used in this analysis, growth in the number of ultimate adopters is allowed. The curves shape is determined by an initial market penetration estimate, growth rate of the technical market potential, and two factors described as *internal market influence* and *external market influence*.

The cumulative market penetration factors reflect the economic potential multiplied by the non-economic screening factor (maximum market potential) and by the Bass model market cumulative market penetration estimate.

Once the market penetration is determined, the competing technology shares within a size/utility bin are based on a *logit function* calculated on the comparison of the system paybacks. The greatest market share goes to the lowest cost technology, but more expensive technologies receive some market share depending on how close they are to the technology with the lowest payback. (This technology allocation feature is part of the EEA CHP model that is not specifically used for this analysis.)

Two cases were run to show the effects of providing an economic stimulus for CHP market penetration consisting of a capital cost reduction of $500/kW for all CHP systems 5 MW and below. The results of the base case, without incentives, are shown in Table E-13. Table E-14 shows the results of the $500/kW incentive case.

Table E-13. Market Penetration Results for Base Case

CHP Measurement	2010	2015	2020	2025
Cumulative Market Penetraiton (MW)				
Industrial	31	265	496	597
Commercial/Institutional	2	74	171	223
Total	33	339	668	820
Avoided Cooling	0	3	8	8
Scenario Grand Total	33	342	675	829
Annual Electric Energy (Million kWh)				
Industrial	380	1859	3613	4,518
Commercial/Institutional	29	430	1101	1,530
Total	409	2289	4714	6,048
Avoided Cooling	0	6	21	30
Scenario Grand Total	409	2,295	4,735	6,078
Incremental Onsite Fuel (billion Btu/year)				
Industrial	1313	10,700	19,824	23,758
Commercial/Institutional	97	2,823	6,483	8,417
Total	1,410	13,524	26,307	32,174
Cumulative Investment (million 2006$)	$33	$362	$731	$910
Cumulative Incentive Payments (Million 2006$)	$0	$0	$4	$7

Note: Incentive Payments in the Base Case represent fuel cell tax credits

Table E-14. Market Penetration Results for $500/kW Incentive Case

CHP Measurement	2010	2015	2020	2025
Cumulative Market Penetraiton (MW)				
Industrial	39	347	661	800
Commercial/Institutional	12	177	386	492
Total	51	523	1047	1,292
Avoided Cooling	2	17	31	32
Scenario Grand Total	53	541	1,078	1,323
Annual Electric Energy (Million kWh)				
Industrial	401	2013	4345	5,645
Commercial/Institutional	49	764	2172	3,071
Total	450	2776	6516	8,716
Avoided Cooling	2	22	77	114
Scenario Grand Total	453	2,799	6,594	8,830
Incremental Onsite Fuel (billion Btu/year)				
Industrial	1545	13,406	25,380	30,630
Commercial/Institutional	358	6,274	13,743	17,513
Total	1,903	19,680	39,123	48,142
Cumulative Investment (million 2006$)	$45	$442	$864	$1,056
Cumulative Incentive Payments (Million 2006$)	$17	$191	$417	$538

APPENDIX F – ONSITE SOLAR ASSESSMENT

Introduction

Pennsylvania is part of a growing trend throughout the U.S. as states seek to establish and meet ambitious and aggressive alternative energy goals. This document was commissioned as part of a broader assessment of clean energy options in Pennsylvania being completed by the American Council for an Energy Efficient Economy (ACEEE). This document assesses the technical and market potential for increased solar energy use in Pennsylvania, and is directed at state environmental and energy staff involved in designing and implementing programs and initiatives for achieving state goals. Solar technologies addressed include:

- Photovoltaics (PV) that produce electricity from the sun;
- Solar hot water (SHW) used for household radiant heating, domestic hot water, and/or process needs in industrial and commercial facilities; and
- Solar hot air (SHA) used for space heating in buildings.

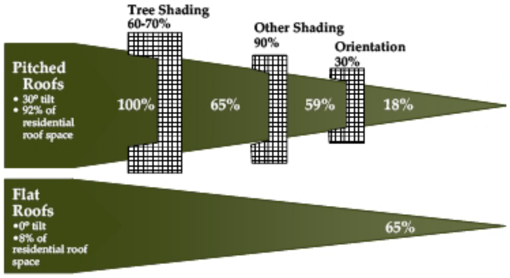
The following information is provided for each of the technologies:

- A description of the technology as well as key information on current use, commercial availability, cost, manufacturing, and the installation infrastructure in Pennsylvania.
- The technical and market potential for increased solar energy use in Pennsylvania.
- Program development issues and factors affecting significant expansion of solar markets in Pennsylvania.
- Conclusions and recommendations for further market transformation.

Methodology for Assessing Technical Potential

A starting point for assessing future solar energy potential in Pennsylvania is to estimate the overall technical potential for solar electricity, solar water heating, and solar air heating. In this document, technical potential is defined as the upper limit for future solar energy use based on the building stock, available roof space, and other key characteristics of Pennsylvania. Technical potential represents a theoretical solar energy use target without regard to cost or market demand. Estimates of technical potential provide a framework for further analysis of the level of market penetration that public policies and programs can seek to accomplish.

The methodology used for estimating PV, solar hot water, and solar air heating technical potential is modeled after and builds upon NREL's *2008 Rooftop Photovoltaics Market Penetration Scenarios*[27] report. The available residential roof area is calculated as a weighted average based on EIA Residential Energy Consumption Survey (RECS) data of residential floor space and the number of floors in single family and multifamily buildings in Pennsylvania, and the metropolitan areas of Philadelphia and Pittsburgh. The total available roof area is constrained by shading, roof pitch, and orientation. Additionally, the roof area with solar access is proportionally shared by PV and SHW, with SHW being given priority due to its restriction to onsite usage. The 18% NREL solar access factor bounds the quantity of residential single family homes with potential for SHW, and of that only a portion of the roof area is allocated to meet the average water heating MMBTU requirements in Pennsylvania. Multifamily apartment buildings are assumed to have flat roofs and a solar access factor of 65%. The balance of the total roof area with solar access not used by SHW to meet the building water needs is allotted to siting PV.



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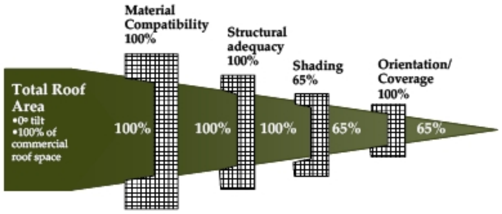
[27] http://www.nrel.gov/docs/fy08osti/42306.pdf



Similarly, the roof area for commercial buildings is calculated as a weighted average of floor space and the number of floors from Commercial Buildings Energy Consumption Survey (CBECS) data. Commercial buildings have a high solar access factor due to the limited amount of shading and restrictions from for flat roofs. The comparatively low ratio of hot water demand to roof area combined with high solar access offers opportunities for much larger individual PV systems (on average). Space and process heating demands in commercial and industrial buildings, although limited in scope, can be met with solar air-heating technologies mounted to the façade of the building. The available façade area is calculated as the product of the average roof width with solar access and the average building height.

Methodology for Assessing Market Potential

In addition to assessing technical potential for PV in Pennsylvania, an initial scenario-based analysis of roof-top PV market potential was conducted. This high level analysis provides a framework for assessing policy direction, market development opportunities, market barriers, and public and private investment needs. The objectives of the market potential analyses are to:

- Provide policy makers with background information and a framework that can be used to assess current plans and policies with regard to long-term targets.
- Provide potential market actors with broad indicators of market scale and development opportunities.

Building upon the scenario results, policy makers and planners can develop more detailed policy maps, goals, program design strategies, and action plans needed to realize the exciting potential solar roof-tops have in Pennsylvania's energy future. In addition, new and existing market actors can utilize the scenario results as a foundation for developing more detailed business plans that are required to attract new investment and generate sustainable industry growth.

The fundamental structure and components of the market potential scenario analysis are summarized in Table F-1 below.

Table F-1. Structure and Components of Market Potential Analysis for Rooftop PV

Element	Structure	Key Assumptions/ Results
Market Growth	Simple compound annual growth	Residential: 40% Commercial: 30%
Years of Direct Market Incentives	Incentives follow a simple linear decline based on estimated number of years to market effectiveness	Residential: 8 years Commercial: 5 years
Projected 5-Year Market Development Budget	High level projection of 5-year budget for market development strategies and incentives	Residential: $65 million Commercial: $40 million
Projected Installations	High level estimate of cumulative capacity and number of systems installed during the 2009-2013	Residential: ~7,100 systems ~28 MW Commercial: ~550 systems ~40 MW

In essence, the market potential scenario provides a framework for the levels of market investment and activity that can be expected if Pennsylvania begins to capture the solar rooftop potential in a sustained fashion. The growth rates implied are rapid, but consistent with industry experience from other states and countries. There are a number of policy barriers and strategies that can either hinder or help to accelerate progress towards these goals. They are discussed below in each of the technology specific sections of the report.

Using Photovoltaics to Produce Solar Electricity in Pennsylvania

Technology Description

The use of photovoltaics to produce electricity from the sun is growing rapidly throughout the world. PV panels derive their name from the photovoltaic effect which converts light energy (photons) to electricity. Solar electric systems based on this effect are used to produce electricity for a wide variety of applications ranging from power supplies for small consumer products, such as watches and calculators, to installations with over one megawatt of peak power output. PV systems provide reliable power for remote applications, such as off-grid homes, navigation buoys, and the international space station. Increasingly, over the last decade, they also provide power for end uses that are connected to the conventional electric power grid. This assessment is focused on PV applications that are grid connected, located on rooftops, and provide power directly to Pennsylvania's electric power system.

Photovoltaics produce electricity any time the sun is shining. The efficiencies with which a solar cell converts energy from sunlight to direct current electricity ranges from 7% to 17%, according to materials and cell type. The majority of photovoltaic modules consist of the same types of silicon-based semi-conductor materials found in computers and other electronic products. Modules are very durable and have expected service lives of 20-25 years.

Solar cells produce direct current electricity. For grid-connected applications, an inverter is needed to convert power produced by the solar cells to alternating current. Inverters are fully commercialized, off-the-shelf solid state electronic power conditioning devices designed and selected to match the current and voltage outputs of a particular PV system. Inverters also function to prevent PV systems from feeding electricity back to the utility grid when there is a power outage. Other "balance of system" components include wiring and connection devices, mounting structures, and hardware.

In Pennsylvania, a photovoltaic system with a peak output of one kilowatt will produce approximately 1,000 to 1,200 kilowatt hours annually and consist of roughly 100 square feet of solar cells (assuming 12% cell efficiency). In this study, PV performance Is determined using the PVWatts[28] calculator program, based on solar intensity measurements in Pennsylvania. Statewide potential is estimated on an average capacity factor of 1,050 kWh per 1 kW of DC capacity per 100 square feet of panel area. Regional values of 1,116 kWh/kW and 1,017 kWh/kW are used for the metropolitan areas of Philadelphia and Pittsburgh, respectively.

Current PV Use in Pennsylvania

As of late 2008, the existing PV market in Pennsylvania consisted of the following:

- A total of **242 interconnected and net metered PV systems** statewide with a total approximate capacity of 895 kW (as documented by the AEPS 2007 Annual Report). These consist primarily of small residential solar electric systems with an average size of 3.7 kW.[29] In addition, at least one solar industry professional in Pennsylvania reports knowledge of numerous other PV systems located around the state financed privately or with funds available from programs such as DEP's *Energy Harvest* and *PEDA* grant programs. [30]

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[28] PVWatts is a performance calculator for grid-connect ed PV systems developed by the National Renewable Energy Laboratory (NREL). Specifc data for the state of Pennsylvania is at the website: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/Pennsylvania/.

[29] 2007 Annual Report: Alternative Energy Portfolio Standards Act of 2004.

[30] Personal communication, Ron Celentano, Vice President, Mid-Atlantic Solar Energy Industries Association Celentano Energy Services, Wyndmoor, Pennsylvania, January 5, 2009.

Overall, it is estimated that PV systems reported by the AEPS and by industry professionals (combined) total 1.5 to 2 MW of capacity as of late 2008. To date, these systems have typically been designed, installed, and maintained by relatively small- to medium-sized locally owned companies that specialize in solar installation. The equipment is manufactured out of state, or in other countries.

- **One utility-scale PV systems with a capacity of 3 MW was completed in 2008 and a 1.5 MW system is** projected to come online in 2009. These larger systems tend to evolve from negotiated contracts between the generation facility and utilities to provide for mandated solar PV renewable portfolio standard set asides. Due to the size and scope of developing utility scale solar installations, developers of such projects are typically national companies (such as Conergy, Sunpower and SunEdison) who develop larger scale solar electric projects across multiple states.

Until recently, PV modules used in Pennsylvania were manufactured elsewhere by national and/or global manufacturers. However, this is beginning to change. Pennsylvania-based Solar Power Industries, Inc. formed in 2003 currently produces muticrystalline solar ingots, wafers, cells, and modules on a commercial basis, and plans to expand production and their workforce at a second location in the state.[31] In 2007, the company made 90 tons of ingots, 240 million dm^2 of wafers, 3.5 MW of cells, and 200 kW of PV modules.[32] In addition, two start-up venture capital companies (AE Polysilicon, Inc. and RSI Silicon Products LLC) recently announced plans to begin producing solar-grade silicon in Pennsylvania by 2010.[33] The availability of solar-grade silicon locally, combined with growing markets for PV in Pennsylvania and strong public policy support for in-state renewable energy manufacturing, could inspire additional companies to site new PV module manufacturing plants in the state in the future.

PV Technical Potential

Although the use of solar electricity in Pennsylvania is currently far less than 1% of total electrical supply in the state, the technical potential exists for much greater solar electricity use in the future. Two rooftop applications of photovoltaic technologies are included in the estimate of technical potential completed for this study[34]:

- **Residential systems** installed in both new construction and existing homes. A typical residential system averages 3.7 kW installed capacity and takes advantage of utility net metering. Net metering permits the customer to spin their meter backwards when the solar electric system produces more power than is consumed at the home, and to receive retail credit for this power. The applications are assumed in this study to be on a mix of flat apartment roofs and sloping south-oriented applications.
- **Commercial/industrial-sited systems** are generally sized so that they produce power "behind the meter" for the customer, and do not export power to the utility grid since they are not eligible for retail net metering. Nevertheless, although they are not exporting power to the grid, the electric and capacity benefits produced by these systems reduce customer load, and therefore, directly off-set demands on the power grid. The applications are assumed in this study to be horizontal applications.

Following the general analysis methods set forth earlier, key assumptions made to estimate PV technical potential in Pennsylvania are described below and summarized in Table 6.

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[31] "A Brighter Future Under the Sun," Photon International, April 2008, page 48, www.photon-magazine.com.

[32] Ibid.

[33] Op cit.

[34] For simplicity and in recognition of the scope and budget for this document, not included in the analysis are: building integrated photovoltaic systems (BIPV) which are typically integrated architecturally into a building's south-sloping roof or façade; ground-mounted PV systems; utility-scale PV systems; and load control PV applications.

System Performance

- PV performance is determined by the PVWatts[35] calculator program, based on solar intensity measurements in Pennsylvania. Statewide potential is based on an average capacity factor of 1,050 kWh per 1kW of DC capacity per 100 sqft of panel area. Regional values of 1,116 kWh/kW and 1,017 kWh/kW are used for the metropolitan areas of Philadelphia and Pittsburgh, respectively.

Residential Buildings

- In 2007 the US Census estimates Pennsylvania to have approximately 5.5 million residential housing units. Of this total, the metropolitan areas of Philadelphia and Pittsburgh have 1.6 million and 1.1 million housing units respectively.
- 64% of the housing units are single family (attached and detached) homes and 21% exist within multifamily buildings.[36]
- Single family homes
  - The single family home, based on an average weighted square footage per floor and a 30% roof pitch, has an average of 1,500 sq ft of roof area.
  - Following a variation of the methods utilized in the NREL study described earlier, after weighing shading and roof orientation, 18% of single family homes have solar access for SHW systems. An estimated 65 sq ft of the average roof area is needed to meet a standard design that can supply 70% of the annual average onsite hot water needs (or 12.5 MMBTU).
  - The balance of the total roof area with solar access for single family homes is allotted to PV. Due to the opportunity to net meter, system size is not limited to onsite electricity consumption, but rather is set to maximize potential DC capacity. Similarly, this approach does not limit the minimum system size either, but instead offers a bounded PV technical potential.
- Multifamily buildings
  - For multifamily buildings in the mid-Atlantic region, an average roof area of 1,550 sq ft is estimated based on the weighted number of housing units and floors per building.
  - The typical flat roof of apartment buildings offers a significantly higher solar access factor of 65%.
  - Average building annual hot water demand in the mid-Atlantic region is assumed to be half of single family demand and the equivalent sqft of roof area is 32 sq ft.
  - Similar to single family homes, the PV capacity is maximized to the remaining roof area.

Commercial Buildings

- 2002 FedStats data lists the number of firms in Pennsylvania at 874,255, of which 33% are located in the Philadelphia metropolitan area and 20% in Pittsburgh.
- Based on CBECS data, buildings in the mid-Atlantic region have on average, 2.7 firms per building and 8,700 sq ft of roof area.
- Average hot water demand for mid-Atlantic buildings is 145 MMBTU, which is equivalent to 530 sq ft of a SHW system (assuming 5.2 sq ft per MMBTU).

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[35] PVWatts is a performance calculator for grid-connect ed PV systems developed by the National Renewable Energy Laboratory (NREL). Specifc data for the state of Pennsylvania is at the website: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/Pennsylvania/.

[36] 2005 RECS Housing Characteristics by Floorspace and Type

Table F-2. Overview of Methodology for Estimating PV Technical Potential

	SECTOR		
Types of Building	**RESIDENTIAL**		**COMMERCIAL**
	Single Family[37]	**Apartment**	
Data	RECS	RECS	CBECS
Solar Access Area	Weighted sqft / # of floors	Weighted sqft / # of floors	Weighted sqft / # of floors
	18% w/ Solar Access	65% w/ Solar Access	65% w/ Solar Access
	25% SHW / 75% PV	10% SHW / 90% PV	6% SHW / 94% PV
Technology	PV – Photovoltaics		
Performance / Use	1kW / 100sqft 12% Capacity Factor (1,050 kWh per kWDC)		
Intermediate Results	Avg. Single Family Home with Solar Access – 2.5kWDC/250 sq ft Avg Multifamily Building with Solar Access – 9.0kWDC/900 sq ft		

Results of the assessment of PV technical potential are presented in Table F-3 and in Figures F-1 and F-2 to highlight the breakdown of statewide and regional potential. As shown in the table, residential rooftop PV offers a significant opportunity for reducing demand during summer peak periods in constrained metropolitan areas (coincident with high cooling loads) and overall statewide electricity usage.

Table F-3. PV Technical Potential in Pennsylvania

	Photovoltaics (MW dc)	**Photovoltaics** (GWh)
Statewide		
Residential	10,388	10,907
Commercial	17,131	17,987
Total	**27,519**	**28,894**
Philadelphia Metro Area		
Residential	3,070	3,428
Commercial	5,641	6,298
Total	**8,711**	**9,726**
Pittsburgh Metro Area		
Residential	2,097	2,132
Commercial	3,375	3,431
Total	**5,472**	**5,563**

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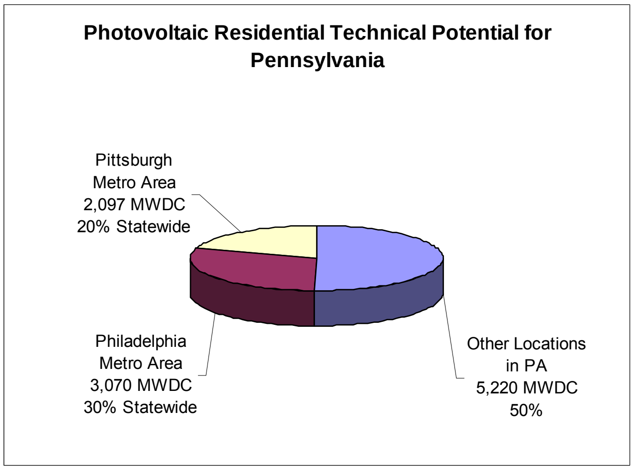
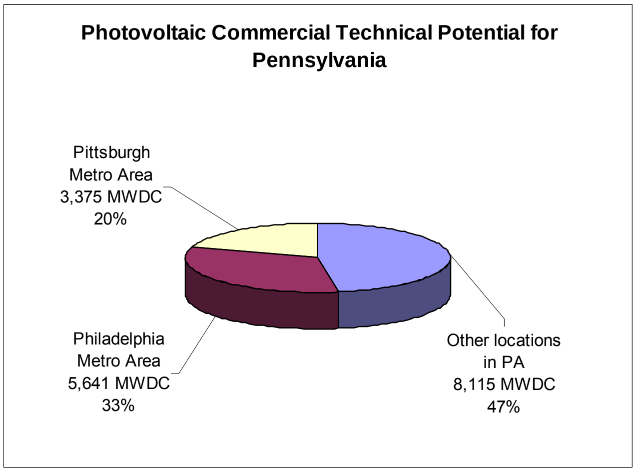
[37] Mobile homes not included in the study.

Figures F-1 and F-2. Technical Potential for Residential and Commercial PV





PV Scenario Analysis of Market Potential

The photovoltaic industry is in a dynamic and rapidly expanding state of development. Recent levels of compound annual growth rates in the range of 30%-50% for manufacturing and installation promise to continue or even accelerate over the next few years.[38] Combined with the extension of the Investment Tax Credit, the initiation of the Alternative Energy Investment Fund and the emerging market for solar Alternative Energy Credits in Pennsylvania provides a strong set of positive market stimulants. Balancing and off-setting these factors to at least some degree are the general economic down-turn and tightened credit markets. It remains to be seen whether reduced consumer spending and investment in durable goods will outweigh the positive impacts of the emerging solar energy market and related policy stimulants.

The scenario analysis of rooftop PV market potential in Pennsylvania completed for this study provides a high level, general reference for how the PV market may develop. The scenario analysis does not replace or represent detailed program design or policy planning, but can be used as a framework to support future work in these areas.

Key drivers for the scenario analysis are the AEPS mandated goals, market values for AECs, the federal tax incentive extension, and AEIF grants or loans (scheduled to launch in for early 2009). The AEIF program is expected to significantly impact the number of installed PV and solar hot water systems in the Pennsylvania residential and small business sectors. Although the incentive program being developed by the Department of Environmental Protection has yet to be released, the original intent was to fund rebates or loans to cover up to 35% of the system installed cost.

A starting point for the analysis is the recent dramatic improvement in the customer economics for installed PV systems (as shown in Figure F-3). With the extension of the federal tax credits (including removal of the $2,000 cap for residential system credits) and new customer incentives available through the AEIF, a 4.0kW PV system in 2009 can be projected to have a positive net present value of $979 over a 25 year operational period. This value represents a $13,681 increase in the net present value for the same system installed the previous year, in 2008. The comparative customer financial returns for the system in 2008 and 2009 are illustrated in the first two bars of Figure 5. Further, even with declining program incentives, the customer financial returns are projected to continue improving, with customer financial return increasing by roughly a factor of three by 2015.

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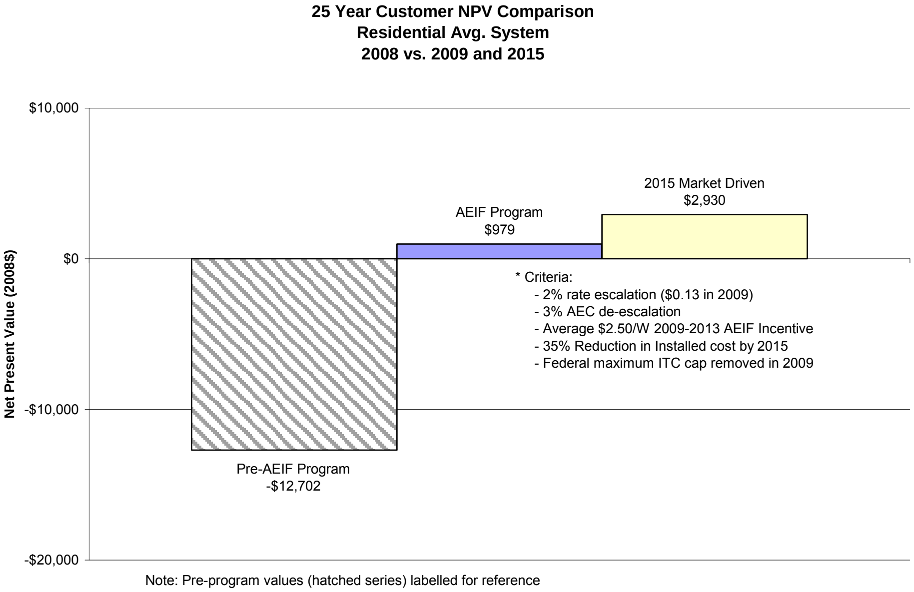
[38] Industry analysts project global production growth rates 107% to 28% over the 2009 to 2012 time horizon. These are accompanied by declines in installed prices of ^% to 11%. Solar Annual 2008: Four Peaks, Photon International Consulting.

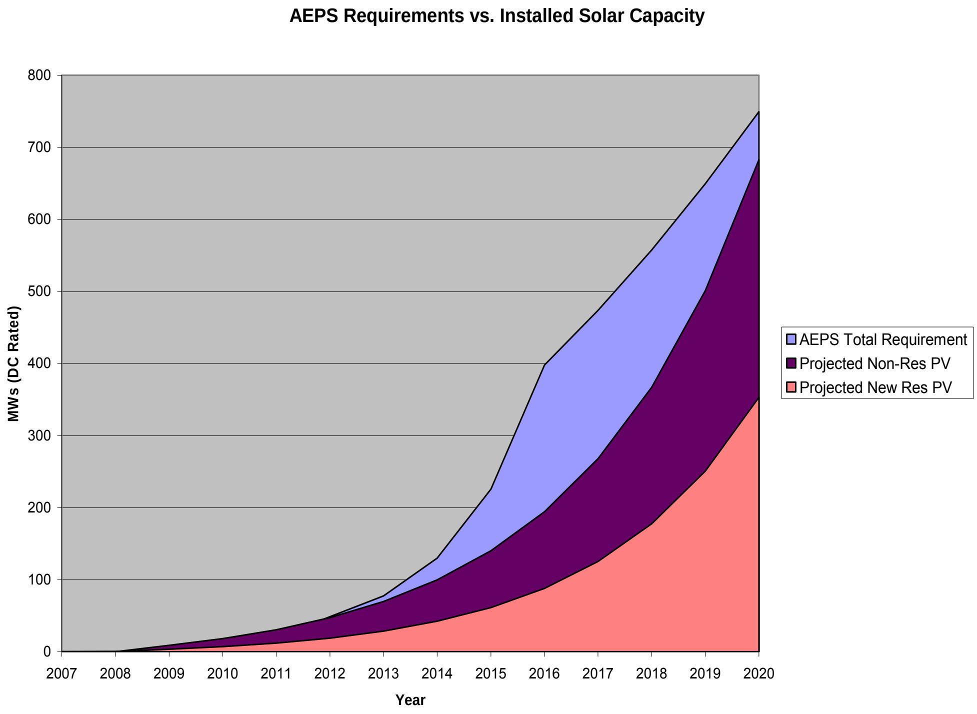
Figure F-3. Comparative Customer Economics for 4 kW Residential PV system



Building on an estimated 40% year over year growth for the residential sector and 30% annual compound growth for the commercial sector projected for Pennsylvania, the program could install more than 7,000 residential and an estimated 550 commercial rooftop PV systems within the five year funding. The incentive budget for the residential market segment is approximately $65M. Over a five year incentive funding cycle, this scenario anticipates a steady reduction of incentive levels from the equivalent of roughly $3.50/DC Watt to $1.75/Watt - while maintaining or increasing customer financial value due to reductions in installed costs as market growth continues.

The market development scenario results suggest that, for the next few years as the utility specific requirements for PV ramp up, program assisted market development should keep pace, or perhaps exceed, the AEPS required results. This is particularly true if additional utility scale projects are developed. As the requirement percentages accelerate, particularly through 2016, a growing need for resources beyond projected market growth in Pennsylvania’s rooftop market is apparent.

Figure F-4. AEPS Requirements vs. Installed Solar Capacity



Factors Affecting PV Market Expansion

The national PV industry frequently notes four "pillars"[39] are needed to ensure sustained orderly development of a cost-effective and viable expanded PV market in any state or region: public policies and incentives, net metering, interconnection, and utility rates. In addition, equipment manufacturing and supply and installation infrastructure are also important. The status of each of these in Pennsylvania and their implications for future market development are discussed below.

PV Public Policies, Incentives, and Standards

As discussed above, Pennsylvania's Alternative Energy Portfolio Standard serves as the cornerstone of the state's energy policy. Currently, utilities meet requirements of the AEPS by purchasing PV Alternative Energy Credits from individual system owners by way of the program's listed solar aggregators. (Each AEC is equivalent to 1 MWh.) In 2007, the average price paid for a solar AEC was $230. There is also an alternative compliance payment mechanism for those who do not procure AECs. The alternative compliance payment level is set at 200% of this average price.

To date, most (but not all) utilities serving Pennsylvania consumers have been able to meet AEPS solar goals by purchasing AEC's from owners of solar electric systems both in-state and from adjacent PJM territories (Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia) at the current rate of solar market expansion (without aggressive new solar programs). However, this is not expected to be the case in the future (without substantial ramp up in alternative energy production in Pennsylvania) due to the rapid increase in AEPS requirements in future years combined with strong demand for AECs in adjacent PJM states with their own aggressive RPS goals to meet.[40]

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[39] http://www.solaralliance.org/downloads/four_pillars.pdf

[40] In December 2008, the PUC calculated the first Pennsylvania solar Alternative Compliance Penalty (ACP) penalty value to be about $528, which according to one solar industry professional implies the average solar AEC was about $264. Although that may be a bit misleading, as the value also included adjusted present values for rebates paid for solar PV projects. Personal Communication, Ron Celentano, Vice President, Mid Atlantic Solar Energy Industries Association Celentano Energy Services, Wyndmoor, Pennsylvania, January 5, 2009.

New public programs and incentives are certain to be needed to stimulate the solar market in Pennsylvania in order to achieve state energy goals.

As also discussed above, the Alternative Energy Investment Fund provides an important mechanism for establishing both public funding to offset upfront costs for solar technologies thru a state incentive and/or rebate program, as well as an economic development fund supporting development (or expansion) of solar manufacturing facilities in the state. The Department of Environmental Protection is tasked with developing programs and guidelines to administer the funds over a period of five years.

At the federal level, in late 2008 the 30% federal investment tax credit for residential solar property was extended through 2016 and the current cap of $2,000 per system was removed for PV. Additionally, the credit was expanded to allow individuals to use the credit to offset Alternative Minimum Tax (AMT) liability. As part of the same bill, the 30% tax credit on commercial solar property was extended to 2016, and was allowed to offset regular taxes and the Alternative Minimum Tax. In addition, electric utilities are no longer exempted from claiming the investment tax credit for solar energy property, and the five-year accelerated depreciation allowance for commercial solar property was made permanent. The extension of the federal investment tax credit thru 2016 and the other changes made to the credit substantially enhance the value of the credit to businesses and utilities. Investment in solar electric and/or solar hot water systems by utilities and/or businesses is already increasing, as a result of these changes.

PV Net Metering and Interconnection

The Pennsylvania PUC started allowing net metering (by utility) beginning in 1998. By 2001, eight Pennsylvania utilities had net metering tariffs in place, along with interconnection requirements. In 2004, standardized net metering was enacted by the PUC requiring all utilities to make net metering available to owners of small, customer-sited, grid-connected alternative energy systems. In 2008, the PUC issued a new rulemaking that updates and enhances the net metering policy from the original version. As set forth in the 2008 order, investor-owned utilities in Pennsylvania must now offer net metering to:

- Residential customers that generate electricity with systems up to 50 kilowatts (kW) in capacity;
- Nonresidential customers with systems up to three megawatts (MW) in capacity; and
- Customers with systems greater than 3 MW but no more than 5 MW who make their systems available to the grid during emergencies, or where a microgrid is in place in order to maintain critical infrastructure.

Additionally, any customer’s net excess generation will now be credited at the utility's retail rate, and carried over to the customer's next bill during a 12-month period. Customers are now permitted to both “virtually” and physically aggregate meters on commonly owned properties within 2 miles of the installed system. These recent enhancements are viewed favorably by the solar industry and are expected to stimulate market demand for customer-sited PV.

In August of 2008, the PUC proposed a standardized interconnection application form and standardized fees for customer-generators.[41] The PUC proposed a series of flat and variable per kW fees to match the levels of review involved in reviewing applications ranging from small residential sized to MW-scale PV systems. A standard application fee of $250 is being considered for a residential or small business sized system (up to 10kW). These enhancements, if enacted, will simplify the customer interconnection process with the utility, and strengthen the economic case for residential and small business PV systems in the state.

PV Utility Rates and Revenue Policies

This is an area that holds a great deal of potential for the long term strength of individual states’ solar PV programs. The key element to the strength of the programs is to tie the high penetration rates with the participation of electric utilities. Additional benefits for a utility are the coincident nature of the PV

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[41] http://www.pabulletin.com/secure/data/vol38/38-31/1413.html

generation with the peak demand periods on the utility. This benefit can be recognized through a time-of-use rate structure that recognizes this benefit.

PV Installation Infrastructure

A significant barrier to achieving Pennsylvania's solar goals and realizing a significant penetration rate of PV in both the residential and commercial sectors is the size of the installation infrastructure in the state. Currently, there are 35 to 40 PV design and installation businesses based in Pennsylvania, and an estimated 5 companies with headquarters in other states who also install PV in Pennsylvania.[42] Combined, it is estimated these companies employ from 250 to 500 PA workers total. However, in many states (including Pennsylvania) rapidly expanding public support for renewable energy (including solar) is inspiring new businesses not previously involved in installing solar to seek solar training and to become involved in solar installations. Examples include electrical contractors, HVAC companies, and housing developers. To date, published lists of solar installers probable underestimate the total number of companies already, or actively preparing to, sell, install, and service solar electric, solar water heating, and solar air heating systems in Pennsylvania. This is expected to change in the near future, as the state prepares to publish a list of those companies qualified to install solar under various state programs. Company interest to be on the state's list, and to therefore be qualified for state incentive and/or rebate programs, will likely result in more complete and comprehensive lists of solar installers in the future.

Industry opinions vary about how much PV can be installed by a company over a given time period. This depends on many factors including: the number of people on a crew; experience of the crew; type and size of installation; site specific details that vary among job sites; etc. The top roof-type PV installer for each of the last 4 years in New York State has found that an experienced PV installation crew can install about 1 kW DC per day of PV (assuming 2 installers on the roof and 3 workers on the ground). In addition, to support a PV installation crew throughout the year, the following is required:

- One half-time engineer to design and specify the PV systems;
- One half-time contract administrator to prepare public incentive applications, complete utility interconnection paperwork, finalize customer contracts, etc.; and
- One half- to full-time sales person (to secure customers). [43]

A Pennsylvania installer believes these estimates are low and reports experienced installers who can install 5 kW in one or two days and up to 20 kW in one week (presumably with a larger crew on larger jobs and/or roof tops.

Assuming (to be conservative) the lower numbers, this indicates that to achieve annual installation rates of approximately 10MW of residential PV systems and 12MW in the commercial sector, a minimum installer and administrative base of approximately 470 employees is needed. At 40% annual growth, the 70MWs of cumulative installed systems will necessitate a similarly rapid growth of maintenance personnel. In many cases, cross-training of existing personnel in the building or electrical trades could support this growth. Further job growth could be expected if Pennsylvania uses funds from the $80M AEIF program or possible federal initiatives in 2009 to support PV manufacturing within the state

In order to reach higher penetration levels within new construction as well as existing homes, it is important to develop a knowledge base within the building community and trades personnel for the potential for reducing an individual home's energy demand with solar. Expansion of the knowledge base with architects and builders, in addition to training electricians in proper installation techniques has shown dramatic results in reducing installed costs and increasing penetration rates in other states. As part of the AEIF program, developing in-state training programs would contribute significantly to the program growth.

PV Manufacturing and Distribution

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[42] "Solar Buyer's Guide 2009, Solar Today, Fall 2008, Volume 22, Number 6, p. 38, www.solartoday.org.

[43] Information provided by the top installer for the past four years participating in the PV Incentive Program administered by the New York State Energy Research and Development Authority, Albany, New York.

As mentioned previously, until recently PV modules used in Pennsylvania were manufactured elsewhere by national and/or global manufacturers. However, this is beginning to change as Solar Power Industries, Inc. expands their production of solar cells commercially, as two start up companies launch plans to produce solar-capable silicon in the state, and as one battery manufacturer and one charge control manufacturer operate in the state. Formation of the Alternative Energy Investment Fund provides the opportunity for Pennsylvania to accelerate efforts to encourage other PV module and/or balance of systems manufacturers to set up manufacturing facilities in the state. States with aggressive and specific PV installation goals (such as California and Massachusetts) have successfully stimulated PV manufacturing growth in their states. PV modules are bulky and expensive to ship, making it preferable for manufacturers to locate new plants close to markets.

Solar Hot Water

Solar energy has been used to heat water for almost a century in the U.S., peaking in the period right before World War II when the demand for copper (used in most solar hot water panels) skyrocketed due to military demand for the material. The SHW industry blossomed again for about a decade in the 1980's, then retracted significantly until recently. The use of solar hot water for residential needs and process needs in commercial and industrial facilities is poised to increase dramatically, as public policymakers and consumers recognize (once again) the attributes and benefits of this clean energy strategy.[44]

Overall, the use of solar energy to heat water is one of the most cost-effective renewable energy applications on the market today. SHW systems supply hot water at a cost of $7-8/MMBTU or $0.03/kWh delivered, which is competitive with (or cheaper than) oil, natural gas, propane, and electric water heaters. There are multiple manufacturers of solar water heating panels both in the U.S. and in other countries, and numerous distributors capable of supplying systems for installation in Pennsylvania. A small (but growing) number of companies in Pennsylvania have solar hot water design, installation, and service expertise.

Technology Description

Solar hot water systems typically consist of a liquid-based collector array, freeze protection strategy, pumping and control system, heat exchanger and solar heated storage tank system. Systems also include interface piping and valves to connect to the backup water heating system, usually a conventional water heater. In retrofit applications, the existing water heater is often used as the backup.

Collector Arrays: For the relatively low temperatures required for domestic hot water, flat plate collectors are most commonly used and provide the most energy per unit cost. These collectors are most commonly single glazed, with selective surface[45] copper absorbers, extruded aluminum frames, and foam insulation. On single family homes, the collectors are typically screwed down to the south-facing roof of the house, with fastening directly to the structure of the roof. For larger installations, and flat roofs in particular, a rack system is needed to install the collectors at the appropriate angle, and to provide necessary structural support and connection to the building. For processed hot water requiring higher temperatures, evacuated tube collectors provide higher temperature water through a greater portion of the year.

Pumps and Controls: Pumps can be powered by electricity from the building's AC power supply, or from DC electricity produced by a small photovoltaic (PV) panel on the roof. PV driven pumping is increasingly common for residential systems, as it eliminates the need for other controls for the pump: in the simplest systems, when the sun shines, the pump runs. AC pumps typically use a differential controller that operates the pump whenever the collectors are hot enough to provide additional heat to the storage tank. Electronic controls include tank and collector sensors.

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[44] These systems are not considered in this document for space heating use, due to low cost effectiveness when these systems are applied to a winter load (when solar resource is at its lowest for the year).

[45] Selective surfaces have high solar absorption rates, typically mid 0.90's, and low emittance rates, typically lower than 0.10, in order to boost performance.

Antifreeze Systems: There are many approaches to eliminating freeze damage to collectors. The most common is to run an antifreeze mixture through the collectors, with a heat exchanger to transfer energy to the storage tank. Antifreeze technology has improved in the past decade, with reliable, long life mixtures available. Another often-used approach is “drain-back,” where the fluid in the collectors and exterior piping is drained back to a storage tank within the heated space of the building whenever there is no solar heat to collect. A hybrid incorporates both technologies, for additional freeze protection security.

Storage for smaller systems consist of well-insulated, pressurized tanks, often made for solar hot water systems, with heat exchangers for antifreeze incorporated into the tank. Tanks for larger solar hot water systems may be either pressurized or un-pressurized, depending on costs and on balance of water heating system type. Tank sizes are typically 1.5 gallons of storage per square foot of flat plate collector. Where solar hot water replaces electric hot water, there may be one or two storage tanks. In the two tank systems, the cold water supply is fed to the first tank, which is heated by the solar system. Pre-heated water from this tank is fed to the second tank, which is often a conventional electric, tank-type water heater, which will heat the water further if needed. A lower cost system uses a single tank, with the electric back-up element in the top and solar heat applied to the bottom of the tank. Performance of the single-tank system is reduced somewhat, due to lower effective storage volume, but the cost is lower.

Several vendors have taken steps to simplify system design and lower installation costs by developing pre-packaged systems for single-family residential solar hot water. Larger systems require site- and application-specific designs.

System Scale and Performance: A solar hot water s system is typically sized to meet one half to two thirds of the annual solar hot water load of a building. Smaller solar fractions typically result in more usable energy per square foot of collector, due to higher efficiencies at lower storage temperatures. Even lower solar fractions will boost efficiency somewhat further, but small systems may represent a loss of opportunity to capture further savings. The summer usage of hot water also plays a role in system sizing, as heat collected must be removed from the system, even if there is no hot water load. Solar collector area ranges from about 32 to 128 square feet for a residential single family system (or 2 to 4 panels) to 300 to 2,000 square feet for industrial thermal needs.

Current Solar Hot Water Use in Pennsylvania

Unlike customer-sited PV systems that require net metering and interconnection agreements with the local utility, solar hot water systems currently involve only a transaction between the customer and installer. Based upon telephone interviews with installers that work with both PV and solar hot water (SHW), it is estimated that SHW systems track currently at about 25% of PV installation rates. This general criteria estimates the SHW market in Pennsylvania at:

- A total of **60 SDHW systems** statewide with a total approximate generation capacity of 750 MMBTU annually. An average system typically meets 60-70% of a household’s annual hot water needs. Similar to PV, SHW systems are typically designed, installed, and maintained by small to medium-sized locally owned companies that specialize in solar installation. To date, there has been little adoption by traditional plumbing/building contractors due to limited consumer demand, lack of training and experience with the technology in the plumbing trades, and the relatively high upfront cost compared to other water heating options. Similar to PV, the equipment currently being installed is manufactured out of state or in other countries.

Solar Hot Water Technical Potential

Two applications of solar hot water technologies are included in the estimate of rooftop solar hot water technical potential completed for this study:[46]

- **Residential systems** installed in both new construction and existing homes. A typical home in the mid-Atlantic region uses approximately 17.4 MMBTU annually for water heating.[47] Based on SRCC performance data for Philadelphia, a closed-loop solar hot water system with 65sq.ft of glazed panels would produce 12.5 MMBTU annually, or approximately 70% of an average home's hot water needs. The applications are assumed in this study to be on a mix of flat apartment roofs and sloping south-oriented applications.
- **Commercial/industrial-sited systems** have similar designs to residential systems, but with scaled up versions of piping and storage. An average building in the mid-Atlantic region uses approximately 145 MMBTU annually for water heating[48]. Based on SRCC performance data for Philadelphia, a closed-loop solar hot water system with 530 sq ft of glazed panels produces 100 MMBTU annually, or about 70% of annual demand. The applications are assumed in this study to be horizontal applications.

Following the general analysis methods discussed above, key assumptions made to estimate SHW technical potential are described below and summarized in Table 8.

System Performance

- SHW performance is based on a closed-loop, glycol based system with annual savings of 12.5 MMBTU per 65 sq ft of collector area.

Residential Buildings

- Single family homes
  - The single family home, based on an average weighted square footage per floor and a 30% roof pitch, has an average of 1500 sq ft of roof area.
  - Following a variation of the methods utilized in the NREL study described earlier, after weighting shading suitability of roof materials, roof orientation, the mix of rural and urban housing and other considerations, at minimum 18% of single family homes have the solar access for SHW systems. An estimated 65 sq ft of average roof area is needed to meet a standard design that supplies 70% of the annual average onsite hot water needs (or 12.5 MMBTU).
- Multifamily buildings
  - Average housing unit's annual hot water demand in the mid-Atlantic region is assumed to be half of single family demand and requires a proportionate area of 32 sq ft of roof area.

Commercial Buildings

- Average hot water demand for mid-Atlantic buildings is 145 MMBTU or 530 sq ft of roof area.

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[46] For simplicity and due to budget parameters, not included in the assessment are solar hot water systems for pools. However, solar pool heating is a very cost-effective means to reduce fossil fuel use. To date, solar pool heating has not typically been eligible for federal or state solar incentives, but should be encouraged as part of such programs in the future.

[47] Energy Information Administration, Residential Energy Consumption Survey.

[48] Energy Information Administration, Commercial Building Energy Consumption Survey

Table F-4. Overview of Methodology for Estimating SHW Technical Potential

	SECTOR:		
Types of Building	**RESIDENTIAL**		**COMMERCIAL**
	Single Family[49]	**Apartment**	
Data	RECS	RECS	CBECS
Solar Access Area	Weighted sqft / # of floors	Weighted sqft / # of floors	Weighted sqft / # of floors
	18% w/ Solar Access	65% w/ Solar Access	65% w/ Solar Access
	25% SHW / 75% PV	10% SHW / 90% PV	6% SHW / 94% PV
Technology	SHW – Solar Hot Water		
Performance / Use	5.2 MMBTU / sqft		
Intermediate results	Avg. Single Family with Solar Access – 12.5 MMBTU/65 sq ft Avg Apartment Building with Solar Access – 18.75 MMBTU/96 sq ft		

Although limited in total potential to the roofs with solar access, SHW could reduce the electric and fossil fuel usage in over 700,000 residential homes and 170,000 apartment buildings and could meet over two thirds of the residents' hot water needs. As shown in Table F-5, the technical potential statewide for solar hot water is 9.1 TBtu annually for the residential sector and 21.3 TBtu for the commercial sector.

Table F-5. Solar Hot Water Technical Potential in Pennsylvania

	Solar Hot Water (TBtu)
Statewide	
Residential	9.1
Commercial	21.3
Total	**30.4**
Philadelphia Metro Area	
Residential	2.7
Commercial	7.0
Total	**9.7**
Pittsburgh Metro Area	
Residential	1.8
Commercial	4.2

Regionally, as shown in Figures F-5 and 6, the metropolitan areas of Philadelphia and Pittsburgh comprise approximately 30% and 20% of the states overall technical potential for both residential and commercial hot water energy consumption.

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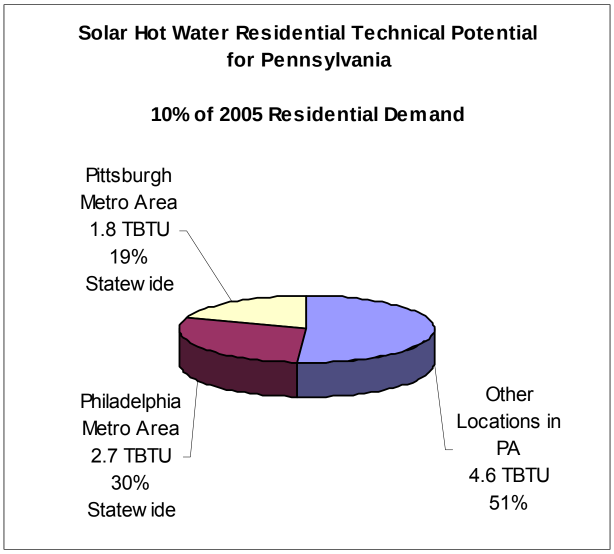
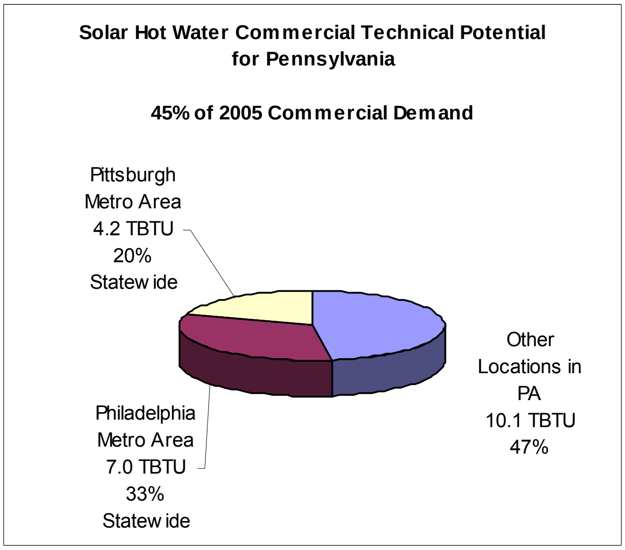
[49] Mobile homes are not included in the study.

Figures F-5 and F-6. Technical Potential for Residential and Commercial SHW





Factors Affecting SHW Market Expansion

Although solar hot water is 50% more efficient than PV in delivered energy and costs approximately half that of PV per unit of energy of delivered, SHW generally lags behind PV in public policy support, marketing, funding, and installer base. Factors affecting SHW market expansion and recommended measures for a strong SHW program in Pennsylvania are discussed below.

Consumer Awareness of SHW

Energy consumers are often not aware of the how well SHW systems can perform and often don't realize that Mid-Atlantic States (such as Pennsylvania) receive more than enough sunshine to make SHW systems cost-competitive with traditional water heating systems. A basic consumer education and awareness program explaining the proven performance and economics of SHW compared to other water heating options could stimulate consumer interest and demand.

SHW Public Policies, Incentives, and Standards

Some states have set specific goals for solar hot water implementation, such as New York State which established a goal of having 1,100 solar hot water systems installed statewide by 2011[50]. Market development support for achieving that goal is now being offered through a variety of state and public entities, including the New York State Department of Public Service and the New York State Energy Research and Development Authority.

A slightly different and less direct approach has been taken thus far in Pennsylvania. Although currently solar hot water is included in AEPS in Tier 2 as an efficiency means for offsetting electric water heating, SHW does not have specific mandated set asides (as PV does). Possibilities for utilizing low cost utility grade meters to measure the generated MMBTUs by individual systems could allow for a stronger role for SHW within the AEPS as could setting specific goals for SHW market penetration.

Extension of the 30% federal investment tax credit, which applies to solar water heating as well as PV, will likely stimulate further growth in the SHW industry. With the new allowance for public utilities to claim the tax credit for installed solar energy property in the 2008 extension, this may also result in new models for large-scale deployment of solar hot water by utilities serving Pennsylvania consumers.

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[50] Clean, Secure Energy and Economic Growth: A Commitment to Renewable Energy and Enhanced Energy Independence: The First Report of the Renewable Energy Task Force to Governor David Paterson, February 2008.

SHW Installation Infrastructure

The SHW installation infrastructure in Pennsylvania is less developed than the PV infrastructure and a relatively small number of companies (estimated to be 5 to 10 maximum) currently design, sell, and install SHW in the state. This could change significantly in the future, if specific and well promoted public goals are established for stimulating increased solar thermal markets (as part of energy efficiency measures and/or public incentive monies provided to stimulate solar markets).

In a study by Canadian Solar Industry Association[51], the job growth for SHW was estimated that 5 full time employees are generated per 1,000 square meters of installed system. Based on a 25% installation rate compared to PV and average systems of 65 sqft or 12.5 MMBTU per home, an additional 400 SHW personnel would be needed to reach the technical potential for SHW estimated in this study.

As noted in the PV section, higher penetration levels of SHW can be reached within new construction and existing homes by expanding the knowledge base within the building community and plumbing trades personnel of the rapid improvements in the solar water heating industry. Following similar programs for training electricians, focused training programs in proper SHW installation techniques could help to reduce installed costs and increasing penetration rates. As part of the AEIF program, developing in-state training programs could contribute significantly to the program growth.

SHW Manufacturing and Distribution

Similar to PV, there are presently no SHW panel manufacturers in Pennsylvania, although a variety of companies distribute and sell panels in the state. As with PV modules, SHW panels are bulky and expensive to ship. Should the state aggressively pursue SHW market development, opportunities exist for potentially combining state economic development goals with allocation of a portion of the Alternative Energy Investment Fund to seeking to attract a SHW panel manufacturer to the state. This could stimulate jobs and revenue while supporting increased use of clean, renewable energy.

Solar Air Heating

Solar energy can provide space heating for buildings either passively through glazing on a south facing wall, or actively using a solar collector with a fan or motor that circulates hot air from the collector to the building. This study assesses the potential for increased active solar heating in buildings in Pennsylvania. Active solar air (or space) heating is a relatively simple and often cost effective way for supplying heat to buildings. Yet, active solar air heating is not widespread in the U.S. (now or in the past). To date, most manufacturers of solar panels have focused on PV or hot water panels, rather than on air heating technologies.

Technology Description

The unglazed transpired solar collector (TSC) is used primarily for heating of building ventilation air. Inspire® (manufactured by ATAS International Inc. in Allentown, PA) and Solarwall® (manufactured by Conserval Inc., founded in Canada) are examples of an active solar air heating system. The system consists of perforated metal cladding installed on the south-facing wall of a building. The dark-colored metal cladding is heated by solar radiation. Ventilation fans located at the top of the wall create a low pressure zone in the cavity between the cladding and the building, drawing solar-heated outside air through tiny holes in the perforated metal panels. The warmed air rises in the cavity to a plenum at the top of the wall, where it is ducted to provide solar-heated ventilation air to the building's ventilation system. Solar heat displaces electricity used for heating ventilation air, at the end use.

In the summer, warm air between the panels and the building rises and is ventilated through holes at the top of the cladding. Fresh ventilation air is drawn directly into the building by way of by-pass dampers. These transpired solar collectors can be used in both new and retrofit applications. In new construction, the system replaces conventional wall cladding, for some cost savings.

System Scale and Performance: This technology is typically applied to buildings that have large, daytime ventilation loads and south-facing walls on which to install the technology. (The system can

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[51] The Job Creation Potential of Solar Energy in Canada, January 2005.

be installed on off-south walls, but performance is degraded.) Solar collection efficiencies are quite high (as high as 75% are reported) due to convective surface losses being captured by the surface air film continuously being drawn in through the numerous surface holes. Energy delivered by a transpired collector in Pennsylvania is estimated at 184 kBtu/square foot-year. For a 2,500 square foot installation the average annual production is 1,840 MMBtu/year or 6,278 MWh/year.

Typically, active solar space heating collectors supply hot air at a cost of about $140 per MMBtu or $25 per square foot, which is competitive with (or lower than) traditional fuels in certain settings.

Current Solar Air Heating Use in Pennsylvania

Due to the application of this technology to a limited segment of the market that can use year round air pre-heating, it significantly trails SHW and PV in market penetration. Conserval Systems Inc. (a leading national solar air heating company, currently has no installations in Pennsylvania, although they do have some projects in the proposal stage. Atas International. Inc. based in Allentown has a 3,600 sqft system installed on their manufacturing facility but has not yet experienced strong market demand for solar air heating in Pennsylvania. A Conserval proposed design for a facility in Pittsburgh, Pennsylvania has the following specifications:

- The system would be 2,500 sq ft in area, or approximately 15% of the building's heated floor space. Annual energy savings would be 466 MMBTU, which includes a percentage of the incoming solar irradiation, recaptured building heat loss, and air destratification savings.
- Agricultural use for crop drying is not addressed in this study, but offers a potentially significant fuel savings that could be achieved through a focused industry specific program.

Currently, solar air heating systems are generally designed in conjunction with the original equipment manufacturer, but are installed and maintained by building and HVAC contractors. There has been little adoption of solar air heating by traditional HVAC/building contractors due to limited consumer demand, lack of training and experience with the technology, and the relatively high upfront cost compared to other space heating options.

SAH Technical Potential

Similar to SHW, the technical potential for SHA in Pennsylvania is a significantly smaller subset of the overall technical potential due to both its limitation to onsite air pre-heating usage and the tendency to use in economically justifiable process or high air exchange buildings. The estimates for roof area outlined in the PV section are applied with the additional assumptions listed below and summarized in Table 10.

System Performance

- SAH performance is based on a SolarWall air heating system with annual savings of 184 MMBTU per 1000 sq ft of collector area.

Commercial Buildings

- Although often used for process pre-heating, this study limits the scope to commercial buildings with high space heating and air exchange requirements. An applicable factor of 30% is used, based on CBECS regional percentages for warehouses, healthcare and food service buildings. Average space heating demand for mid-Atlantic commercial buildings is 145 MMBTU or 530 sq ft of facade area, but typical installations are greater than 2000 sqft for the sub-segment of commercial buildings (warehouses, healthcare and food services).

Table F-6. Overview of Methodology for Estimating Solar Air Heating Technical Potential

	SECTOR:
Types of Building	**COMMERCIAL**
Data	CBECS
Solar Access Area	Weighted sqft / # of floors
	65% w/ Solar Access
	6% SHW / 94% PV
	Façade: Roof width x Avg Building Height x 30% (C&I Factor)
Technology	SAH – Solar Air Heating
Performance / Use	0.184 MMBTU / sqft Approximately 25% of Commercial Buildings
Intermediate results	Avg. Commercial Building –368 MMBTU/2000 sqft

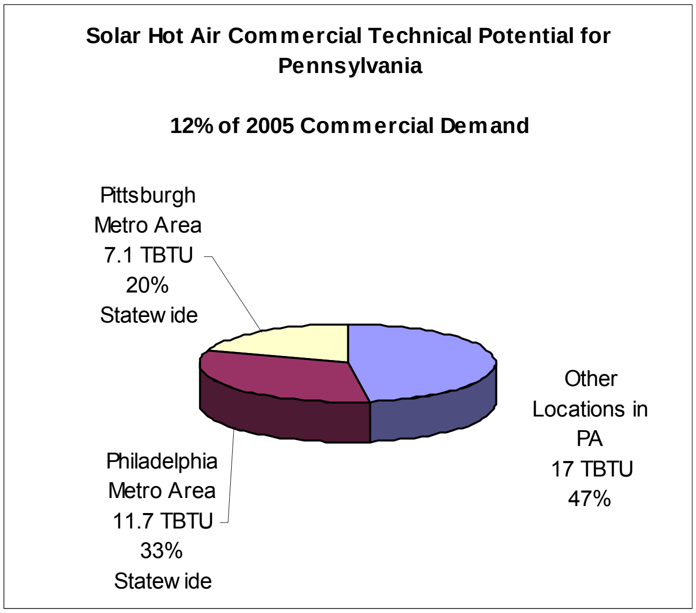
Direct air pre-heating through solar collector panels can be one of the most efficient renewable means for reducing process and space heat needs. This study bounded the technical potential by the percentage of commercial facilities in Pennsylvania that fit the traditional application of the technology. Further market development for both residential and commercial applications could expand this potential dramatically. As shown in Table F-7, it is estimated that the space heat fuel consumption of over 90,000 commercial buildings could be reduced by 36 TBtus with solar space heating, which represents approximately 12% of the statewide demand for commercial space heating.

Table F-7. Solar Air Heating Technical Potential

	Solar Hot Air (TBtu)
Statewide:	
Commercial	36.0
Philadelphia Metro Area:	
Commercial	11.7
Pittsburgh Metro Area:	
Commercial	7.1

Regionally, as shown in Figure F-7, the metropolitan areas of Philadelphia and Pittsburgh comprise approximately 30% and 20% respectively of the state's overall technical potential for commercial solar space heating.

Figure F-7: Regional Distribution of Technical Potential for Commercial Solar Air Heating



Factors Affecting SAH Market Expansion

Although solar air heating has a lower efficiency in delivered solar energy than SHW due to the thermal capacity of water vs. air, it leads the three technologies in lowest cost per delivered MMBTU ($136/MMBTU). It continues to lag significantly behind PV & SHW in public policy support, marketing, funding, and installer base, but could significantly benefit from a focused program initiative. Factors affecting SAH market expansion and recommended measures for a strong solar air heating program in Pennsylvania are discussed below.

Market Awareness of SAH

Industrial and commercial buildings are often designed without consideration of the economic benefits and associated fuel savings of SAH systems and building orientation for capitalizing on the solar resource. An awareness program explaining the proven performance and economics of SAH compared to traditional space heating with natural gas or electricity could stimulate interest and demand within both the new construction and existing building market.

SAH Public Policies, Incentives, and Standards

Similar to SHW, solar air heating does not generate electricity, but rather offsets in some cases the energy consumption of electric space or process heating. The most significant policy initiative currently in the state, AEPS, treats this technology as an efficiency means and places it in the Tier 2 category with waste coal and large-scale hydro (among others). This grouping does not set specific set-aside goals for the technology and poses significant challenges for business owners looking to improve the economics of a SAH system.

Similar to PV and SHW, extension of the 30% federal investment tax credit applies to solar space and process heating systems and will continue to provide important incentive for further growth in the industry.

SAH Manufacturing, Distribution, and Installation Infrastructure

The SAH manufacturing, distribution, and installation infrastructure in Pennsylvania is very small, consisting of one Pennsylvania-based companies (Atas) and Canadian-based Conserval proactively proposing systems designs in the state. As noted in the SHW section, this could change significantly if specific and well promoted public goals are established for stimulating increased solar thermal markets (as part of energy efficiency measures and/or public incentive monies provided to stimulate solar markets). State supported market development through focused educational initiatives within the agricultural, commercial and industrial sectors, combined with state economic development goals and funding, could stimulate jobs and revenue while supporting increased use of clean, renewable energy.

Conclusions and Recommendations

The solar assessment in this study estimates the technical potential for photovoltaics, solar hot water and solar hot air systems to contribute to Pennsylvania's energy future. Included in the study are the potential for rooftop PV and hot water systems and façade mounted solar hot air systems. The results indicate that PV systems have the technical potential to off set roughly 20% of total electric requirements. Solar hot water systems can off set the equivalent of roughly 22% of hot water heating use, and solar hot air systems can off set approximately 12% of total space heating.

These technical potentials far outweigh current use, and the statewide target established for the growth of solar electric generation. For example the AEPS solar target of 860 MW of PV installed by 2021, is equivalent to only about 3% of the total technical roof top PV potential of more than 27gigawatts. It is therefore clear that technical potential limits do not constrain Pennsylvania from reaching current targets for solar market development.

Our research also included analysis of a market development scenario for photovoltaics, based on current and expected future market conditions. This scenario suggests that market development activities, such as the AEIF investments, are likely to provide a large portion of the required AEPS goals but that additional supporting market development strategies and investments will be required.

Key factors affecting future solar markets in Pennsylvania include:

- Informed consumers aware of the energy price stability, supply reliability, and economic benefits of increased use of solar for electricity, water heating, and space heating. Continuation and expansion of consumer education and awareness programs are an important component of stimulating market demand for solar technologies.
- Incentives to help offset the upfront cost of purchasing solar systems, and financing to help consumers "cash flow" the increased initial cost compared to traditional energy systems.
- Consistent availability of solar panels and balance of system (BOS) components. Worldwide demand for PV panels is growing very rapidly, and PV companies are building new manufacturing plants throughout the world as quickly as they can to keep up with demand. Increased production of SHW and SAH panels is also expected in the future, and some states are intentionally linking their renewable energy goals with their economic development objectives. Clear, ambitious, multi-year solar implementation goals in Pennsylvania could be the cornerstone of an increased 'green jobs' and 'green manufacturing' initiative in the state.
- A sufficient solar business infrastructure able to serve potentially rapidly expanding solar markets in each region of the state. Presently, certain regions of Pennsylvania are under served by existing solar businesses, and existing companies serving Pennsylvania customers are not scaled up (yet) to accomplish the market expansion envisioned and quantified in this study. Workforce development initiatives can help expand the installation infrastructure, while stimulating local jobs.
- Availability of trained and qualified solar designers, installers, and service technicians to work for an expanding solar industry infrastructure. States with rapidly growing solar markets (such as California, New Jersey and New York) are experiencing a rapid increase in interest in worker training for PV within the electrical trades and unions, and for SHW within the plumbing and heating trades and unions. Interest in SHA tends to be strongest among green architects designers, and builders. These trends are expected to occur in Pennsylvania, as the solar market grows in the state as well.

APPENDIX G – THE DEEPER MODEL AND MACRO ANALYSIS

The Dynamic Energy Efficiency Policy Evaluation Routine—or the DEEPER Model—is a 15-sector quasi-dynamic input-output impact model of the U.S. economy.[52] Although an updated model with a new name, the model has a 15-year history of use and development. See, for example, Laitner, Bernow, and DeCicco (1998) and Laitner and Hanson (2007) for a review of past modeling efforts. The model is generally used to evaluate the macroeconomic impacts of a variety of energy efficiency (including renewable energy) and climate policies at both the state and national level. The national model now evaluates policies for the period 2008 through 2050. Although, the DEEPER Model for the Pennsylvania specific analysis will cover the period between 2008 through 2025. As it is now designed, the model solves for the set of energy prices that achieves a desired and exogenously determined level of greenhouse gas emissions (below some previously defined reference case). Although the model does include non-CO_2 emissions and other emissions reduction opportunities, it currently focuses on energy-related CO_2 emissions and on the prices, policies, and programs necessary to achieve the desired emissions reductions. DEEPER is an Excel-based analytical tool that consists generally of six sets of key modules or groups of worksheets. These six sets of modules now include:

Global data: The information in this module consists of the economic time series data and key model coefficients and parameters necessary to generate the final model results. The time series data includes the projected reference case energy quantities such as trillion Btus and kilowatt-hours, as well as the key energy prices associated with their use. It also includes the projected gross domestic product, wages and salary earnings, and levels of employment as well as information on key technology cost and performance characteristics. The sources of economic information include data from the Energy Information Administration, the Bureau of Economic Analysis, the Bureau of Labor Statistics, and Economy.com. The cost and performance characterization of key technologies is derived from available studies completed by ACEEE and others, as well as data from the Energy Information Administration's (EIA) National Energy Modeling System (NEMS). One of the more critical assumptions in this study is that alternative patterns of electricity consumption will change and/or defer the mix of investments in conventional power plants. Although we can independently generate these impacts within DEEPER, we can also substitute assumptions from the ICF Integrated Planning Model (IPM) and similar models as they may have different characterizations of avoided costs or alternative patterns of power plant investment and spending.

Macroeconomic model: This set of modules contains the "production recipe" for the region's economy for a given "base year"—in this case, 2006, which is the latest year for which a complete set of economic accounts are available for the regional economy. The I-O data, currently purchased from the Minnesota IMPLAN Group (IMPLAN 2007), is essentially a set of input-output accounts that specify how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other. In this case, the model is now designed to evaluate impacts for 15 different sectors, including: Agriculture, Oil and Gas Extraction, Coal Mining, Other Mining, Electric Utilities, Natural Gas Distribution, Construction, Manufacturing, Wholesale Trade, Transportation and Other Public Utilities (including water and sewage), Retail Trade, Services, Finance, Government, and Households.

Investment, expenditures and energy savings: Based on the scenarios mapped into the model, this worksheet translates the energy policies into a dynamic array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. It estimates the needed investment path for an alternative mix of energy efficiency and other technologies (including efficiency gains on both the end-use and the supply side). It also provides an estimate of the avoided investments needed by the electric generation sector. These quantities and expenditures feed

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[52] There is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a manageable sized model. If we choose to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be done easily. If we wish to expand the number of sectors, that would take some minor programming changes or adjustments to reflect the larger matrix.

directly into the final demand module of the model which then provides the accounting that is needed to generate the set of annual changes in final demand (see the related module description below).

Price dynamics: There are two critical drivers that impact energy prices within DEEPER. The first is a set of carbon charges that are added to retail prices of energy depending on the level of desired level of emission reductions and also depending on the available set of alternatives to achieve those reductions. The second is the price of energy as it might be affected by changed consumption patterns. In this case DEEPER employs an independent algorithm to generate energy price impacts as they reflect changed demand. Hence, the reduced demand for natural gas in the end-use sectors, for example, might offset increased demand by utility generators. If the net change is a decrease in total natural gas consumption, the wellhead prices might be lowered. Depending on the magnitude of the carbon charge, the change in retail prices might either be higher or lower than the set of reference case prices. This, in turn, will impact the demand for energy as it is reflected in the appropriate modules. In effect, then, DEEPER scenarios rely on both a change in prices and quantities to reflect changes in overall investments and expenditures.

Final demand: Once the changes in spending and investments have been established and adjusted to reflect changes in prices within the other modules of DEEPER, the net spending changes in each year of the model are converted into sector-specific changes in final demand. This, in turn, drives the input-output model according to the following predictive model:

$X = (I-A)^{-1} * Y$

where:

X = total industry output by sector
I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)
A = the production or accounting matrix also consisting of a set of production coefficients for each row and column within the matrix
Y = final demand, which is a column of net changes in final demand by sector

This set of relationships can also be interpreted as

$\Delta X = (I-A)^{-1} * \Delta Y$

which reads, a change in total sector output equals $(I-A)^{-1}$ times a change in final demand for each sector. Employment quantities are adjusted annually according to exogenous assumptions about labor productivity in each of the sectors (based on Bureau of Labor Statistics forecasts).

Results: For each year of the analytical time horizon (again out to 2025 for the Pennsylvania specific analysis), the model copies each set of results into this module in a way that can also be exported to a separate report.

Further results from Pennsylvania's DEEPER analysis is provided to show macroeconomic trends between 5-year time periods. Although similar 2015 & 2025 results were presented in the body of this report, differences between 5-year time periods offer more reference points for the reader to understand Pennsylvania's macroeconomic trends under the efficiency scenario. This section highlights the net changes Pennsylvania's economy will experience as the result of our efficiency scenario.

Table G-1. Changes in Pennsylvania Electricity Production and Financial Impacts from Energy Efficiency Policy Scenario: 2010, 2015, 2020 & 2025

(Millions of 2006 $)	**2010**	**2015**	**2020**	**2025**
Efficiency Gains (GWh)	1,261	13,711	28,722	42,119
Change from Reference Case	0	0	0	0
Policy Cost	178	340	404	509
Investment	447	1,162	1,385	1,662
Annual Consumer Outlays	$366	$1,387	$2,091	$2,491
Annual Electricity Savings	$120	$2,154	$4,756	$7,242
Electricity Supply Cost Adjustment	$33	$774	$1,666	$2,387
Net Consumer Savings	-$213	$766	$2,665	$4,751
Net Cumulative Energy Savings	-$233	$1,018	$9,657	$29,327

The macroeconomic module of the DEEPER model traces how each set of changes works or ripples its way through the Pennsylvania economy in each year of the assessment period, see Table G-1. This module estimates the number of jobs and amount of wages each sector provides the Pennsylvania economy. Changes in sectoral spending will be provided in Table G-2 below.

Table G-2. Changes in Sector Spending (Millions of 2006 Dollars)

Sector	**2010**	**2015**	**2020**	**2025**
Agriculture	-$1.1	$0.5	$24.5	$52.3
Oil and Gas Extraction	-$1.0	-$2.8	$14.1	$34.7
Coal Mining	$0.0	-$0.1	$0.4	$0.9
Other Mining	-$0.6	-$1.7	$8.7	$21.3
Construction	$222.2	-$312.6	$55.9	$663.5
Manufacturing	-$5.7	$91.7	$373.8	$677.8
Petroleum Refining	-$6.4	-$7.3	$119.9	$270.2
Electric Utility Services	-$21.3	-$548.9	-$1,182.6	-$1,712.1
Natural Gas Utility Services	-$49.9	-$307.6	-$851.2	-$1,404.9
Transportation Other Public Utilities	-$6.7	-$0.3	$19.5	$42.7
Wholesale Trade	-$13.7	$189.7	$537.7	$904.8
Services	-$25.3	$623.9	$1,708.0	$2,858.4
Financial Services	$1.7	-$132.6	-$295.9	-$436.6
Governmental Services	$6.9	$27.1	$52.7	$82.2

There are other support spreadsheets as well as routines in visual basic programming that support the automated generation of model results and reporting. For more detail on the model assumptions and economic relationships, please refer to the forthcoming model documentation (Laitner 2009). For a review of how an I-O framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2007). While not an equilibrium model we borrow from some key concepts of mapping technology representation into DEEPER using the general scheme outlined in Laitner and Hanson (2007).