Using Targeted Energy Efficiency Programs to Reduce Peak Electrical Demand and Address Electric System Reliability Problems

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EXECUTIVE SUMMARY

In the summers of 1998, 1999, and 2000, electric system reliability problems were regular front-page news. The reliability of the power system, however, should not be viewed as only a short-term, summertime issue. In much of the country, electricity use (particularly peak demand) is expected to grow rapidly, and power supplies will probably be strained for many years to come.

A range of solutions have been proposed to address electric system reliability problems and reduce the likelihood of power outages. These solutions include constructing new power plants, expanding the transmission and distribution system, implementing load control programs, improving energy efficiency, and investing in distributed generation resources (e.g., combined heat and power systems [CHP]). An approach limited to only supply-side solutions would create additional pollution as well as political opposition to siting these new facilities. Energy efficiency, on the other hand, offers a low-cost alternative that reduces the need for additional central station generation and distribution capacity while reducing pollutant emissions and saving consumers and businesses billions of dollars. In this report, we discuss how demand-side efficiency could make a substantial and cost-effective contribution to addressing power reliability problems.

With reliability problems occurring in the short term and likely to persist for awhile, utility companies (or other appropriate program administrators) should design and implement programs that will have a substantial impact on peak demand within the next 1–5 years. In order to achieve this objective, the programs must:

C Save energy at peak hours.
• Have enough impact on dominant loads that massive savings would result;
C Use technologies and practices that are already proven and in the market; and
C Build upon program designs that have been demonstrated to be successful.

Based on these criteria, three areas jump out as having the most potential: efficient heating, ventilating, and air conditioning (HVAC) equipment; proper installation, maintenance, and use of HVAC and other building systems; and commercial sector lighting.

In the following sections we recommend six programs that could cover these end-uses. The six programs are:

1. new and replacement residential cooling systems;
2. residential cooling systems tune-up and repair;
3. commercial and industrial HVAC equipment;
4. commercial building retrocommissioning and maintenance;

5. commercial and industrial lighting retrofit acceleration; and
6. commercial and industrial lighting design enhancement.

Next, we discuss information on these suggested programs, including data on estimated program costs and impacts. Overall we find that each of these programs would likely be cost-effective relative to other peak demand supply or peak demand reduction options, particularly when the value of both energy and peak demand savings are included in the analysis. Further details on each program, including suggestions for program planning, and savings and cost-effectiveness analysis, are provided in Appendix C.

Overall, the six recommended programs could reduce peak electrical demand in 2010 by about 64,000 megawatts (MW). These savings would negate about 40% of the growth in peak demand predicted over the next decade. About 45% of the savings would be due to the new residential air conditioner program. The commercial retrocommissioning program and the commercial lighting upgrade programs would each account for about 15% of the savings, while the other three programs would account for 11% (residential air conditioning repair), 8% (commercial lighting design), and 6% (commercial HVAC equipment).

In order to capture the peak demand savings possible from energy efficiency, we recommend the following actions.

- Policy-makers should consider efficiency programs as an *essential complement* to supply-side programs and load management in efforts to assure system reliability.

- Utility companies (or other appropriate program administrators) should begin developing and implementing major peak reduction programs as soon as possible so that programs would start by the end of 2000, and also should undertake sufficient installations so that they begin to have an impact on the 2001 summer peak.

- State utility commissions should encourage, or even require, utilities or other organizations under their jurisdiction to develop and implement energy efficiency programs targeted at reducing peak demand.

- The U.S. Department of Energy (DOE) should provide technical assistance to states, utilities, and other program sponsors to help them develop and implement energy efficiency and other programs targeting peak demand.

- States should adopt funding mechanisms for energy efficiency and other public benefit fund (PBF) programs. In addition, as part of federal restructuring legislation, the federal government should encourage states to set up and expand PBFs by establishing a national fund to match state PBF expenditures.

- Congress should also consider pending tax credits on high-efficiency residential air conditioners and energy-saving new commercial buildings as a complement to the programs listed here.

THE PROBLEM: GROWING RELIABILITY PROBLEMS

In the summers of 1998, 1999, and 2000, electric system reliability problems were regular front-page news. In 1998 there were power interruptions, brownouts, and requests for voluntary curtailments in Chicago, Colorado, Michigan, and New York (Cowart 1999). In 1999, blackouts occurred in New York City, Chicago, Long Island, New Jersey, the Delmarva Peninsula, and the South-Central States (DOE 2000a). In June 2000, rolling blackouts occurred in California and there were close calls in several other regions (e.g., Pennsylvania/New Jersey and New England) (Howe 2000; Norr 2000; Penn Future 2000). During this past summer, supplies were extremely tight in New England, New York, California, and the Southwest (NERC 2000a); if had not been a cool summer in much of the country, reliability problems could have been much worse.

The summer months are particularly taxing on the electric system. Soaring temperatures lead to increased peak demand as consumers and businesses crank up their air conditioners to stay cool. The greatest demand for air conditioning generally occurs in the mid-afternoon hours, coinciding with the highest demand for other electricity uses such as for lighting businesses and powering factories. High temperatures also negatively impact the performance of electricity generation, transmission, and distribution equipment, reducing the availability of generation and transmission capacity and increasing the likelihood of distribution system failures. As a result, the electricity system is called on to meet the highest demand at the time when its components are most prone to problems.

Electric reliability problems tend to be of two types — regional and local. Regional problems occur throughout a utility service area, or often throughout a regional power pool, when available generating capacity is unable to meet peak demand. For example, on July 23, 1999, Entergy, a major utility serving parts of Louisiana, Texas, Arkansas, and Mississippi, needed 900 MW of additional power to meet customer demand. To make up this shortfall, Entergy had to resort to "rolling blackouts" in which it shut off power to thousands of customers at a time, then after 20–30 minutes, restored power to these customers and shut off power to another group of customers (DOE 2000a). Local problems occur in more geographically limited areas and can be due to a shortage of adequate transmission or distribution capacity to get power into a particular local area (as was the cause of the rolling blackouts in San Francisco on June 14, 2000) or can be due to failure of distribution equipment such as transformers or switches that are most prone to fail when high demand and high temperatures coincide (as was the cause of the 1999 blackouts in Chicago and New York City). The distinction between regional and local problems is far from absolute; some reliability problems are due to a combination of factors and lie in between these two categories. For example, on July 5-8, 1999, a heat wave in the New Jersey/Delaware area caused both a regional shortage of power and localized cable and switchgear problems, leading to the failure of several substations and rotating blackouts in a portion of the region (DOE 2000a).

The reliability of the power system should not be viewed as only a short-term issue. In much of the country, electricity use (particularly peak demand) is expected to grow rapidly, and power supplies will probably be strained for many years to come. For example, the California Independent System Operator expects peak demand to grow about 1,000 MW annually through the end of their forecast period (CEC 1999). Likewise, a March 2000 reliability study on the Northwest power system concluded that "the probability of a generation shortfall reaches approximately 24% by 2003." The study recommended that in order to reduce this probability to 5% (the traditional utility planning target), about 3,000 MW of new resources (generating capacity and voluntary load reductions) will be needed (NPPC 2000). Nationwide, the North American Electric Reliability Council (comprised of most of the power generating and distribution companies in the United States) predicts that peak demand will grow an average of 1.8% annually over the next 9 years. Projected growth in summer peak in the different regions of the country totals 128,000 MW over this period (NERC 2000a).

A range of solutions have been proposed to address electric system reliability problems and reduce the likelihood of power outages, including constructing new power plants, expanding the transmission and distribution system, implementing load control programs, improving energy efficiency, and investing in distributed generation resources (e.g., combined heat and power systems). Building additional generation, transmission, and distribution capacity can be very expensive, particularly when the power is only needed for a limited number of hours each year. For example, a recent analysis found that:

> In Florida, 15% of the capacity in the system is needed less than 1% of the hours in a year. For the sake of analysis assume it is 0.5% of the hours in a year. Therefore, a new combined cycle turbine generator built to run only 43.5 hours a year would need a price of more than $1,260/MWh [$1.26/kWh] during those hours to be profitable (Energy Insight 1998).

Upgrading transmission systems can also be costly. For example, the Long Island Power Authority just completed a $65 million project to build a new transmission line to serve portions of eastern Long Island. The line has a capacity of about 120 MW (i.e., $542/kilowatt [kW]) but with $7 million additional investment, the capacity could be doubled (i.e., a total cost of $300/kW) (Milhous 1999; PII 2000). Moreover, transmission upgrades are often only a short-term solution to reliability problems because with continued growth in peak demand, in many regions peak demand will soon exceed available generation capacity. And heat waves often extend across power pools, meaning that power is not available to transmit from one region to another, even if transmission capacity is available. For example, on July 5-8, 1999, heat waves hit the New England, New York, and Pennsylvania/Jersey/Maryland (PJM) power pools simultaneously, causing brownouts and blackouts across the region. Furthermore, additional power generation imposes costs to the environment and public health — electricity generation is a leading source of the air pollution that contributes to global warming and increases the incidence and severity of asthma and other respiratory and cardiopulmonary diseases. These environmental and health issues, along with concerns about the disappearance of open space and added noise, are driving community opposition to power plants and transmission line construction across the country.

In contrast, energy efficiency offers a low-cost alternative that could reduce the need for additional central station generation and distribution capacity while reducing pollutant emissions and saving consumers and businesses billions of dollars. In the following sections we discuss how demand-side efficiency could make a substantial and cost-effective contribution to addressing power reliability problems. Load control and distributed generation could also help reduce peak demand and are discussed in the sidebar. However, given projected growth in peak demand of more than 100,000 MW, load control and distributed generation would be only part of the solution to reliability problems — additional steps would also be needed.

Load Control, Distributed Generation, and Fuel Switching

Load control, meaning shifting some loads from peak periods to off-peak periods, could make a significant contribution to reducing peak demand. Many utilities (as well as some non-utility organizations) pay customers to participate in programs under which the utility installs radio-controlled switches to turn air conditioners and water heaters off during peak demand periods. Programs also give large customers discount rates for "interruptible loads" that the utility can shut off on short notice. And some experimental programs are allowing customers to participate in regional power bidding pools, but instead of bidding to supply power, customers can bid to interrupt power to their facilities (CAISO 2000). In 1998 (the last year for which complete data are available), load control programs reduced peak demand by 13,640 MW (EIA 1999a). Given the substantial contributions to date of load control programs, it is unclear how much more these programs could save but clearly there is some additional potential.

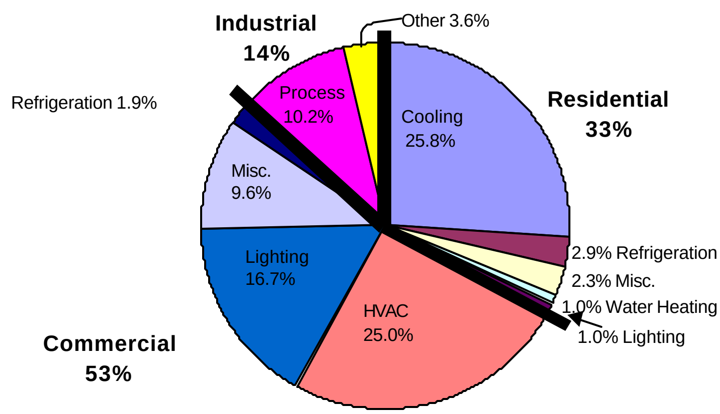
Distributed generation includes renewable generation technologies (e.g,. wind and biomass) as well as on-site generation systems. One type of on-site system that is receiving a lot of attention is combined heat and power systems, which produce both electricity and thermal energy, resulting in the capture of up to 80% of the energy contained in the fuel. A major initiative is now underway in the United States to double CHP capacity over the next 10 years. This goal is ambitious and would require about 50,000 MW of new capacity by 2010; given the need for a ramp-up period, perhaps 10,000–20,000 MW of additional capacity could result over the next 5 years (Elliott 2000). To this total, projections indicate that on the order of 3,000 MW of renewable generation capacity is likely to be added over the next 5 years (EIA 1999b).

Another approach for reducing peak demand would be to switch some electric loads to other energy sources such as natural gas. Since air conditioning is a major driver of peak demand, air conditioning is a particularly attractive load for fuel switching. Over the last decade, much progress has been made in developing improved gas cooling equipment including many new chillers and unitary air conditioners, which use a natural gas engine in lieu of an electric motor to drive the compressor. The American Gas Cooling Center estimated that units with a total cooling capacity of 20–30 million tons have been installed, including annual installations of about 0.2 million tons, and current targets are to increase annual additions by 0.5 million tons in 5 years (Occhionero 2000). If we roughly assume that this equipment displaces electric air conditioners and chillers with an average efficiency of 0.8 kW/ton, total peak capacity savings could be on the order of 2,000 MW over the next 5 years if these targets are met.

Reducing Peak Demand Through Energy Efficiency

Since increased peak demand is the heart of reliability problems, efforts designed to reduce peak demand must be an important part of any strategy to improve electric system reliability. The difference in load between a normal day and a peak day is primarily driven by air conditioning, and thus strategies to reduce cooling loads and improve the efficiency of cooling systems must be a central part of any strategy to reduce peak loads. In addition, commercial lighting loads are generally substantial during weekday afternoons when peak demand generally occurs. Key loads on a typical peak demand day are illustrated in Figure 1.

Figure 1. Distribution of Summer Peak Demand by End-Use for New Jersey



Source: XENERGY Inc. 1999.

Economics

Energy efficiency programs directed at reducing peak demand can often be cheaper per kW saved than the cost of alternative power supply and power reduction strategies. For example, a recent Commonwealth Edison pilot project in Chicago commissioned (checked and reset controls and other system components) the cooling systems in 11 large commercial buildings. The work reduced peak demand by about 2 MW, reducing demand at an average cost to the utility of $132/kW saved (Kessler et al. 1999). Assuming an average measure life of 7 years (as discussed in Appendix C), this works out to $24/kW-year (the standard index of the cost of electric generation capacity), substantially less than the typical $47/kW-year capital cost of a new peaking power plant (see Appendix A). Similarly, the incremental cost of a high-efficiency commercial chiller or packaged cooling system relative to standard equipment is on the order of $31-44/kW-year (see Table 1 below). In other cases, efficiency investments may cost a little more per kW-year but would still be cost-effective because power plants have significant operating costs while efficient equipment has lower operating costs than standard-efficiency equipment. For example, while a residential air conditioning tune-up costs nearly $100/kW-year, due to the substantial energy savings, it costs on the order of $0.07 per kilowatt-hour (kWh) saved,[1] significantly less than the cost of summertime power in most regions of the United States.

[1] Measure costs, life, and discount rate per Appendix A. Energy savings based on Appendix C and a national average energy use for residential central air conditioners of 2,109 kWh/year (EIA 1999c).

Similarly, advanced lighting design costs more than $100/kW-year, but on an annual basis the energy savings work out to approximately $0.03/kWh, significantly less than the average annual electric rate paid by most commercial customers.[2] Table 1 compares the approximate costs of a variety of peak demand-reduction and power supply strategies.

Table 1. Cost/kW for Different Demand Reduction and Power Supply Strategies

Option	Cost/Peak kW-year
Supply-Side	
Peaking power plant (capital only)	$47
Peaking power (including operating costs)	$55
Transmission upgrade (e.g., S. Fork of Long Island)	$22
Local distribution upgrades	$20–60
Note: In many cases both new power plants *and* transmission/distribution upgrades would be needed — doing one without the other would go only part of the way in addressing some reliability problems.	
Demand-Side	
More efficient chiller	$44
More efficient packaged commercial cooling system	$31
More efficient residential air conditioners	$62
Residential cooling system tune-up	$98
Commissioning of existing commercial buildings	$58
Commercial lighting upgrade	$25
Commercial lighting design	$125
Residential air conditioning load control	$53
Residential water heater load control	$92
Commercial & industrial interruptible rates	$44
Note: Demand-side measures also save energy; when the value of these energy savings is considered, even measures costing $100/kW-year or more would be cost-effective. Details on these calculations are provided in Appendix A.	

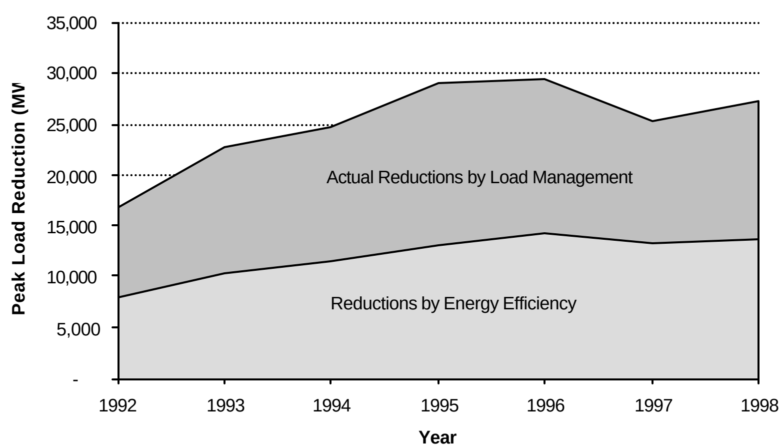
In addition to being cost-effective from a direct economic point of view, efficiency investments often produce indirect benefits as well, such as better lighting, more effective cooling, improved worker productivity, and the health care savings and environmental benefits associated with reduced emissions from power plants.

Historic Experience

[2] Calculation based on data in Appendix A and further assuming that lights operate an average of 4,000 hours/year.

Energy efficiency is already contributing substantially to reducing peak demand. Since the 1980s, many utilities have operated energy efficiency and load management programs. Nationwide, these programs have yielded significant peak demand savings. As shown in Figure 2, actual demand savings climbed steadily from 1992 to1995, with 1995 savings of 29,600 MW, which was 4.8% of summer peak demand in that year.[3]

Figure 2. Actual Peak Load Reductions from Energy Efficiency and Load Management Programs, 1992-1998



Source: ACEEE analysis of Energy Information Administration reports and Form 861 data.

Unfortunately, in the mid-1990s, as electric industry restructuring began, many utilities cut back spending on their energy efficiency and load management programs in order to accelerate depreciation on high-cost assets and to reduce short-term rates. As a result, peak demand savings began to fall in absolute terms (e.g., actual nationwide demand reductions in 1997 were 14% lower than in 1996). Furthermore, available[4] nationwide peak reductions fell even more relative to previous utility power supply plans. For example, available peak reductions in 1998 were 24% lower than plans for 1998 made in 1993 (see Figure 3).[5] Thus, cutbacks in energy efficiency and load management programs have contributed to rising peak demand, and by extension, to our current reliability problems.

New Opportunities

It is time to reverse these recent trends and reinvigorate energy efficiency programs. Past programs illustrate the magnitude of savings that can be achieved, but significantly greater savings would be

[3] Calculation based on summer peak demand in 1995 of 620,249 MW (NERC 2000b).

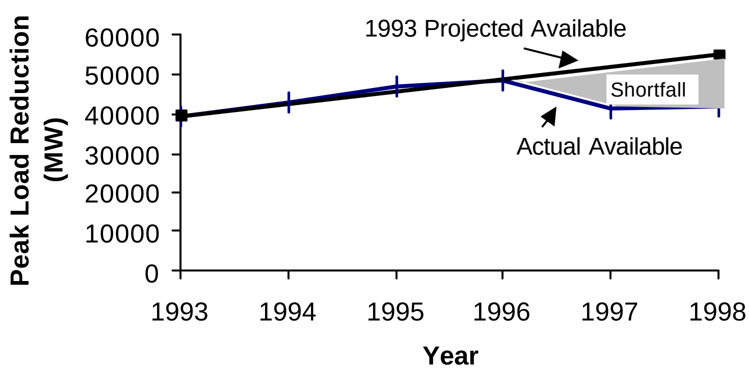
[4] "Available" demand reductions include actual reductions plus load management reductions that are under contract but are not called upon.

[5] In 1993, utilities projected available peak load reductions in 1998 of 55,163 MW (EIA 1995). In 1998, available peak load reductions were only 41,430 MW (EIA 1999a).

possible by focusing on new technologies and services that were not readily available in the mid-1990s. In the sections below we discuss some of the most prominent of these opportunities.

Furthermore, programs targeting peak demand could be be a useful complement to other energy efficiency strategies now being pursued. In several regions of the country, utilities and regional organizations are operating *market transformation* programs that seek to make specific energy-saving goods and services normal practice by addressing market barriers that impede their use. Among the measures being pursued in this manner are proper air conditioner installation and maintenance, building commissioning, and advanced lighting design practices. Programs to promote these measures in the short term in order to reduce peak demand could help to accelerate long-term market transformation. Likewise, these longer-term market transformation efforts could build on the momentum generated by short-term peak reduction programs in order to continue to reduce peak demand in the longer term.

Figure 3. Projected vs. Actual Available Peak Reductions for 1998



Source: ACEEE analysis of Energy Information Administration reports and Form 861 data.

KEY EFFICIENCY PROGRAM OPTIONS

With reliability problems occurring in the short term and likely to persist for awhile, utility companies (or other appropriate program administrators) should design and implement programs that will have a substantial impact on peak demand within the next 1–5 years. In order to achieve this objective, the programs must:

- Save energy at peak hours;
- Have enough impact on dominant loads that massive savings will result;
- Use technologies and practices that are already proven and in the market; and
- Build upon program designs that have been demonstrated to be successful.

Based on these criteria, three areas jump out as having the most potential: efficient HVAC equipment; proper installation, maintenance, and use of HVAC and other building systems; and commercial sector lighting.

Within each of these areas are an array of activities to save energy and reduce peak demand. For most, a complex of actions oriented at vendors, designers, and service providers would be required to achieve the largest possible savings. This brings out an important point. Big savings could be achieved through efficiency in a relatively modest time, but only if the sponsor commits to managing a small family of initiatives, each of which would require some technical and market sophistication. The days where utilities could garner 70% of the available savings through simple lighting rebates are over. As we note in the lighting section, the simplest initiatives may result in the fastest savings, but these would diminish quickly in comparison to what would happen without the program.

These areas of opportunity include systems in the residential, commercial, and industrial sectors. Given large differences in how equipment and services are provided to the residential and commercial/industrial sectors, separate programs should be organized to serve these sectors.

In the following sections we describe six specific recommended programs. Additional details on these suggested programs, including information on estimated program costs and impacts, are provided in Appendix C. The six programs are:

1. new and replacement residential cooling systems;
2. residential cooling systems tune-up and repair;
3. commercial and industrial HVAC equipment;
4. commercial building retrocommissioning and maintenance;
5. commercial and industrial lighting retrofit acceleration; and
6. commercial and industrial lighting design enhancement.

New and Replacement Residential Cooling Systems Program

In most regions of the country, central cooling dominates the residential contribution to peak demands. In New Jersey, for example, residential customers are estimated to represent approximately one-third of system peak demands and central air conditioners are estimated to represent 52% of that contribution (XENERGY Inc. 1999).[6] The operating efficiency of the equipment has a major bearing on

[6] Note that central air conditioning represents 63% of single family homes' contribution to the New Jersey system peak demand (XENERGY Inc.1999). Note also that the saturation of central air conditioning is growing, in part because the saturation in new construction is much higher (almost universal) than in existing homes. Thus, the contribution of residential HVAC systems to utility system peaks would also be higher in states with a larger share of single-family homes and a younger housing stock, as well as in states with warmer climates, higher saturations

the magnitude of that contribution. Operating efficiency is itself a function of two major factors: the nameplate efficiency of the equipment itself and the way it is installed and maintained.

Over 6 million residential-sized central air conditioners and heat pumps are sold annually in the United States. Unfortunately, fewer than 4% of all new units sold in the United States have efficiency ratings of seasonal energy efficiency ratio (SEER) 13 or higher; roughly three-quarters are rated at or near SEER 10, the lowest efficiency rating available on the market (ARI 1998). In addition, numerous studies from around the country suggest that new central air conditioners and heat pumps are oversized by an average of 1 ton of capacity. The same studies also suggest that roughly 70% of all new systems have inadequate airflow, incorrect levels of refrigerant, or both (Neme, Proctor, & Nadel 1999). The savings potential from addressing both of these opportunities — combined energy savings of 40–50% and combined peak demand savings of 25–40% — would be substantial.

We designed our recommendations in Appendix C to address both of these opportunities. We model our recommendation program after similar programs in New Jersey. The program's goal would be to transform the market to one in which quality installations of high-efficiency equipment become common practice. It would accomplish that goal through a combination of interrelated strategies:

- Incentives for the sale or purchase of high-efficiency equipment for which documentation of proper sizing and installation would be provided;
- Training of HVAC technicians on key elements of quality installations;
- Sales training for contractors (i.e., how to sell efficiency);
- Direct marketing to HVAC distributors and contractors through "circuit riders;"
- Promotion of HVAC technician certification; and
- Aggressive consumer marketing/education campaign on key elements and benefits of efficiency.

Residential Cooling Systems Tune-Up and Repair Program

As noted above, central air conditioners and heat pumps dominate the residential contribution to utility peak demand. They are also usually installed incorrectly, with improper refrigerant charging and inadequate airflow over the coil having particularly adverse impacts on equipment-operating efficiency. These problems persist throughout the life of the equipment. In addition, most central air conditioners and heat pumps are connected to ducted distribution systems that are very leaky, with 20% or more of the air flowing through them leaking to or from the outdoors.[7] Treating both charge/airflow and duct

of central cooling, and below average presence of heavy industry.

[7] The average leakage rate from 19 different studies from across the country was 270 CFM_{25} (CFM=cubic feet per minute) (Neme, Proctor, & Nadel 1999). CFM_{25} is commonly used as a metric for duct leakage because the pressures created when an air handler is "on" typically average about 25 pascals. A typical 3 ton central air

leakage problems on a retrofit basis could save an average of 24% of the energy and 14% of the contribution to peak demand made by the average central air conditioner or heat pump (Neme, Proctor, & Nadel 1999). Moreover, such treatments should improve comfort in the home, reduce maintenance costs, and extend equipment life.

Unfortunately, many HVAC technicians have neither the training nor the tools necessary to diagnose and treat refrigerant charge and airflow problems. Moreover, precious few of the technicians who do have the ability to identify and treat these problems routinely do so. The situation is even worse with respect to leaky duct systems. In most of the country, there are at best a handful of specialists capable of effectively treating duct leakage problems.

We designed our recommendations in Appendix C to address the market barriers to realizing the substantial savings possible from improving the operating efficiency of existing central air conditioners and heat pumps. We model the program after a similar program currently being implemented by Proctor Engineering for San Diego Gas and Electric (SDG&E). The program's long-term goal is to transform the market to one in which there are a number of HVAC technicians capable of diagnosing and treating HVAC efficiency problems working for HVAC firms that see sales of such services as a core part of their business. The program would accomplish that goal through a combination of interrelated strategies:

- Modest consumer incentives for both assessment of HVAC systems and treatment of any problems identified;
- Aggressive consumer marketing campaign to promote the hiring of qualified HVAC contractors to assess and treat operating efficiency problems;
- Direct marketing to HVAC contractors (through "circuit riders") to encourage them to participate in the program;
- Providing interested contractors with: (1) easy-to-use software for guiding diagnosis and treatment of key HVAC operating-efficiency problems; and (2) the training on how to use such software;
- A quality control mechanism to ensure both that any remedial work performed on HVAC systems would be done properly and that any contractors submitting fraudulent data would be identified and removed from the program; and

conditioner should have an airflow rate of 1,200 CFM. Thus, duct leakage of 270 CFM_{25} represents roughly 22% of system airflow.

- A mechanism for referring interested customers to qualified HVAC contractors.

Commercial and Industrial HVAC Equipment Program

Commercial and industrial (C&I) heating, ventilating and air conditioning is probably the single largest contributor to summer peak demand. Yet the HVAC systems on the market today vary substantially in energy efficiency. Peak air conditioning demand could be reduced by an average of about 20% if purchasers chose the most efficient models, rather than average performers. In commercial applications, the high-efficiency systems typically save enough in operating costs to pay back in 3 to 5 years.

The goal of this program is to assure the efficient selection and installation of cooling and air distribution systems in the commercial and industrial sectors. There are two primary components — chiller system efficiency and packaged HVAC system efficiency. In each case, "system efficiency" incorporates efficient equipment, and proper specification, design, and installation. Utilities (or other program sponsors) could significantly reduce peak demand simply by assuring selection of efficient systems, but could save much more through influencing design and installation practices.

There are two major ways to capture the savings from high-efficiency cooling equipment: voluntary programs such as the Consortium for Energy Efficiency's (CEE) packaged equipment standards, and mandatory standards. Both approaches are needed to help reduce demand.

While consumers and commercial buildings could save money by choosing efficient systems, many unitary systems are purchased by building contractors who have no concern with operating cost. Here, mandatory standards would provide the best long-term payoff but voluntary programs would help pave the way. Standards for small commercial systems (expected by 2001) will likely increase performance 10–20%. Setting a strong new federal standard for small commercial air conditioning and heat pump systems could eliminate the need for approximately 4,500 MW of peak generating capacity by 2010, and nearly triple that by 2020 (Thorne, Kubo, & Nadel 2000b). Additional savings would be available from larger systems and also from promotion and incentive programs on small commercial equipment.

For packaged equipment, the proposed program focuses on marketing higher-efficiency units not only to achieve direct effects, but to influence federal standard-setting procedures; high near-term penetration would help support a nearer-term and more stringent standard. The program would also help accelerate acceptance and state and local adoption of the chiller efficiency levels in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) 90.1-1999 standard.

However, there are savings on chiller efficiency available beyond the ASHRAE standard. Furthermore, savings from system design and installation will largely be influenced by market forces because these elements are difficult to incorporate into standards. For these reasons, and also to help increase the political and market receptivity to standards, the program should offer a system of rebates, vendor and customer marketing, technical assistance, and training designed to build market demand for efficient equipment, and good systems design and installation, while also assuring that contractors will be able to meet this demand.

Program success would require a close working relationship with key vendors as well as customers. Implementors must be encouraged to work with customers and to ascend a ladder of sophistication in HVAC system design, as described below:

Step 1. Select efficient equipment.
Step 2. Properly size equipment.
Step 3. Design efficiency into chiller distribution systems and packaged system ducts.
Step 4. Reduce heat-producing loads (e.g., lighting and computers) before sizing and designing large systems.
Step 5. Employ efficient installation and commissioning practices.

While each of these elements adds complexity to the program, the program administrator should add them incrementally as capability is added, and customers should access the program at the level of their own motivation and capability.

Commercial Building Retrocommissioning and Maintenance Program

In most regions of the United States, commercial buildings account for a larger portion of peak demand than any other sector. But very few of the complex cooling, electrical, and distribution systems in these facilities are properly tuned. That's why so many workspaces are either too hot or too cold. Often, the systems were installed improperly; in other cases, they have fallen out of synch as control settings and building uses change. *Retrocommissioning* such buildings — optimizing their energy-using systems — could significantly cut energy use. Instituting good operations and maintenance procedures could add to the savings, as well as help to ensure that savings are maintained over time.

As noted above, a recent Commonwealth Edison pilot project commissioned 11 large commercial buildings in Chicago, reducing peak demand by about 2 MW. Total annual savings were more than 6 million kWh, and nearly half a million dollars. The average cost to the utility per kW saved was $132 (Kessler et al. 1999). Another study found average energy savings of nearly 20% in 44 building commissioning projects on existing commercial buildings. The majority paid for themselves in less than a year (Gregerson 1997). A 1998 study estimated that by 2010, programs to commission existing buildings could reduce U.S. energy use by about 60 billion kWh (Suozzo and Nadel 1998). In addition to saving energy, these improvements would result in substantial peak demand reductions.

One impediment is the limited number of qualified commissioning engineers. And building owners are often unaware of the services commissioning engineers can provide. Both problems could readily be addressed. For example, Oregon's Portland General Electric is promoting commissioning to building owners and paying half the cost of commissioning services for local buildings, along with part of the costs to implement the recommendations (Peterson and Findlay 1999). In New York State, a pilot program to retrocommission chiller systems and reduce peak demand was started in June 2000 and by August 2000 more than 130 participants had signed up. These retrocommissioning projects were implemented in August and September and a report summarizing the program's results is scheduled for completion in late 2000 (Henderson 2000).

Building on these results, we recommend that utilities and other local program implementers operate programs with the goal of promoting widespread *retrocommissioning* (commissioning of existing buildings) and proper maintenance of large commercial buildings. Key program components should include:

- Local market research, to understand the current state of commissioning knowledge and skills among potential commissioning customers and providers and to explore proposed intervention strategies with these audiences;
- Education for building owners and facility managers to familiarize these decision-makers with the opportunities and benefits of commissioning and to provide information on how to obtain quality services;
- Local demonstration projects and case studies to help promote retrocommissioning locally;
- Establishing a benchmarking system to help building owners assess the performance of their buildings relative to other buildings. Such a system could inspire owners of inefficient buildings to explore strategies to improve building performance;
- Active marketing efforts to encourage building owners and managers to retrocommission their buildings;
- Commissioning service provider training and technical assistance to help local engineers gain the skills and experience to provide commissioning services;

- Maintenance staff training and certification to help staff gain skills to improve systems operation including helping to keep buildings in tune after they have been commissioned; and

- Financial incentives to reduce the cost of commissioning services.

Commercial and Industrial Lighting Retrofit Acceleration Program

Overall, lighting accounts for about 25% of summer peak demand in the commercial sector, the second largest share after air conditioning. Lighting energy use could be cut by 30-50% in buildings that have never improved their lighting systems through use of "first wave" technologies that conservation programs have already popularized in new construction (e.g., T-8 lamps, electronic ballasts, compact fluorescent lamps, and metal halide lighting) as well as more advanced measures (e.g., high-quality fixtures, high-intensity fluorescent lamps, improved lighting controls, and good design) (EPA 1999). A study for the California Energy Commission estimated that savings of roughly 33% are available in new buildings, *beyond* California's stringent building codes, with higher savings (on the order of 48%) available in existing buildings (Heschong-Mahone Group 1997).

Nevertheless, more than half of existing commercial building floor area does not yet use the "first-wave" measures. Efficient lighting designs are used in only a small minority of spaces, and control systems that maximize the use of daylight are even less common.

No comprehensive studies of potential overall peak load reduction from more efficient commercial lighting exist. However, estimates discussed below suggest that savings by 2010 could be more than 10,000 MW.

We designed our recommended program to increase the saturation of efficient lighting among existing commercial and industrial buildings. The program would accelerate and broaden the efforts already underway by customers and a wide array of contractors to replace obsolete lighting systems with the more efficient systems that have become common practice for most new construction. This program would be complemented by a separate but related effort to enhance the quality and efficiency of common practice for lighting design, as described below.

Of these two programs, the retrofit acceleration one would likely provide the most peak savings in the 1-3 year time horizon because the hardware for this program would already be available in volume, installation would be relatively easy, and contractors and customers would already be familiar with the measures. However, much of the savings that this program would provide would occur with or without this program progressively in the next 15 years or so as buildings are remodeled and renovated and as equipment wears out. Many of the measures common in to a lighting retrofit program are also now common practice for renovation and remodeling. This means that perhaps a third of the first-year savings might be achieved with or without the program by year 5.[8] In contrast, the design enhancement program discussed below would likely have modest early savings, but would increase in significance after 3 years.

We designed the retrofit acceleration program after the model of established programs that are highly successful, have evolved over more than a decade, and are relatively easy to implement. Key components would be as follows:

- Customers must be provided with a range of technical assistance suitable to the scope of each project.

- Prescriptive and customized rebates must be provided (only for retrofits, not for new construction or major renovations).

- Higher rebate levels, and an optional separate procurement process, must be included to address the additional market barriers that face small businesses (<100 kW). The small business component would provide a minority of the savings and may require higher expenditures per kWh, but would likely have the greatest impacts after 5 years. This is because smaller businesses are less prone to adopt new technology on their own.

- The program must be promoted directly by the utility or other program administrator, but also must be designed to make use of the efforts of energy service companies and other proactive marketers of efficiency.

Commercial and Industrial Lighting Design Enhancement Program

One review of recently constructed and renovated New Jersey buildings estimated cost-effective lighting savings in individual buildings ranging from 5-35% *beyond* common practice for new construction. The additional savings comes from additional design and equipment improvements (Sardinsky 2000). While these estimates were for energy savings, most of the proposed measures would deliver on-peak savings as well. Even higher savings may be possible with new technologies such as individualized user-controlled addressable light fixtures and design for daylighting.

We designed this program to capture these savings by increasing the quality and efficiency of lighting design in new commercial and industrial construction, renovation, and remodels. This program would provide relatively modest savings in the next 3 years because it would largely influence new and

[8] Long-term savings are likely to be largest in markets where remodeling and replacing light fixtures are less common, such as in small buildings and institutions.

replacement systems, and could only influence the building stock as fast as it grows or equipment turns over. However, the benefits would grow significantly as the proportion of the building stock that is constructed, renovated, or remodeled cumulates over several years. As detailed in Appendix C, in a region with significant growth, its market could be as big as 40% of the building stock within 5 years.

This program would support and be enhanced by efforts to achieve state-level adoption and enforcement of the lighting standards in the new ASHRAE standard 90.1-1999. It also would encourage efficiency beyond that standard. The program design would leverage off of efforts by pioneering utilities to develop specific tools to work with the design community.

The central structure of the program is a series of prescriptive and custom rebates, supported by a program of technical assistance. The rebates are similar to those in the retrofit acceleration program described above except that: (1) they are keyed to improvements beyond current practice and codes; (2) the customized rebate takes a larger role; and (3) rebates are based on a portion of the incremental cost to exceed current practice and codes.

For smaller and contractor-designed buildings, lighting design tends to be simple and standardized; contractors rarely analyze lighting system energy use or light output. For these buildings, as a complement to rebates, the program would provide lighting design guidelines as a tool to both train contractors and to build demand for better lighting among owners, managers, and renters. The guidelines also would create a template for distributors, manufacturers, and other "contractor helpers" to specify efficient, high-quality layouts.

SUMMARY OF SAVINGS POTENTIAL FROM THESE PROGRAMS

Overall, the six programs recommended in this report could reduce peak electrical demand in 2010 by about 64,000 MW. About 45% of the savings would be due to the new residential air conditioner program. The commercial retrocommissioning program and the commercial lighting upgrade programs would each account for about 15% of the savings. The other three programs would account for 11% (residential air conditioning repair), 8% (commercial lighting design), and 6% (commercial HVAC equipment). Savings estimates by program are summarized in Table 2. Additional details on these calculations are provided in Appendix B.

Table 2. Summary of Savings Potential from Peak Reduction Programs

Program	Available Peak Savings in 2010 (MW)
New and replacement residential cooling systems	28,777
Residential cooling system tune-up and repair	6,900
Commercial and industrial HVAC equipment	3,900
Commercial building retrocommissioning and maintenance	11,000

Commercial and industrial lighting retrofit acceleration	9,200
Commercial and industrial lighting design enhancement	4,900
TOTAL	63,900 (includes adjustment to eliminate double-counting between programs)

According to the North American Electric Reliability Council, summer peak electrical demand is projected to grow by about 160,000 MW from 1999–2010.[9] Thus, the energy efficiency ideas discussed here, *if* aggressively pursued, could address approximately 40% of expected demand growth over the decade, contributing substantially to addressing peak demand-related reliability problems. Additional savings could be achieved from load management programs and other energy efficiency programs not discussed here.

In addition to reducing shortages in generating capacity, by reducing demand in districts with overtaxed distribution systems, these peak reduction programs could also reduce the incidence of distribution-related reliability problems (such as happened last year in New York City, Chicago, New Jersey, and Long Island). Furthermore, by decreasing energy use, these programs would have additional benefits such as reduced energy costs for customers and less emissions from power plants. Also, as described in detail in Nadel et al. (1997), energy efficiency investments have positive effects on jobs and the economy.

However, achieving these savings would require actions by many people. The alternative is either continued reliability problems, or the higher costs and greater environmental problems associated with supply-side-only solutions.

RECOMMENDATIONS

In order to capture the peak demand savings possible from energy efficiency, we recommend the following actions:

- Policy-makers should consider efficiency programs as an *essential complement* to supply-side programs and load management in efforts to assure system reliability. Efficiency can be effective, low in cost, and provide economic savings directly to ratepayers.

- Utilities (or other appropriate program administrators) should begin developing and implementing major peak reduction programs as soon as possible so that programs would start by the end of 2000, and also should undertake sufficient installations so that they begin to have

[9] NERC (2000a) projects growth of 128,000 MW through 2008. We extend this to 2010 using NERC's projected 1.8% annual growth rate.

an impact on the 2001 summer peak. For example, HVAC distributors typically order equipment for the next cooling season around October — to ensure that these orders contain sufficient high-efficiency equipment, distributors would have to be briefed on program plans before these orders are placed. As these programs "ramp up" over several years, peak demand savings would steadily increase. All too often utilities do not begin summer peak planning until the spring, leaving inadequate time to take demand-side actions.

- State utility commissions should encourage, or even require, utilities or other organizations under their jurisdiction to develop and implement energy efficiency programs targeted at reducing peak demand. In states that have restructured, this responsibility (or at least funding) would generally fall on distribution utilities since they remain regulated monopolies, are the service provider of last resort, and commonly operate other energy efficiency programs. For example, the California Public Service Commission (CPUC) recently ordered utilities in the state to issue a request for proposals to solicit proposals for accelerated programs to reduce demand in the summer of 2001. The CPUC then reviewed the proposals and accepted 15 for implementation, with a total budget of $72 million (CPUC 2000). Likewise, the New York State Public Service Commission recently proposed a set of expanded programs to reduce peak demand in the state (NYDPS 2000). As state commissions consider steps along these lines, they will also need to consider ways to provide utilities with adequate incentives and resources to implement these programs (Moskovitz 2000). Alternatively, other organizations could operate programs such as state governments or Independent System Operators (ISOs). For example, the California legislature recently appropriated funds for the California Energy Commission to operate some programs (California Legislature 2000) and in New York State, a state "Authority" (a semi-independent state agency) will operate the programs.

- DOE should provide technical assistance to states, utilities, and other program sponsors to help them develop and implement energy efficiency and other programs targeting peak demand. During the early 1990's, DOE provided extensive technical assistance to states and utilities on efficiency and related issues, but due to budget cutbacks these efforts have been scaled back dramatically in recent years. DOE and Congress should increase funding for the DOE Electricity Restructuring Program so that DOE can expand the amount of assistance it can provide.

- States should adopt funding mechanisms for energy efficiency and other public benefit programs. To date, twenty states have established a public benefit fund of some type, supported by a small surcharge on distribution service, to fund programs in the broad public interest including energy efficiency, low income, renewable energy, and public interest research and design. These programs have traditionally been funded through electric rates; a PBF is a competitively neutral mechanism for continuing these programs following restructuring (Nadel

& Kushler 2000). States that do not presently have a PBF should enact them; states with minimal PBFs should expand their programs. In addition, as part of federal restructuring legislation, the federal government should encourage states to set up and expand PBFs by establishing a national fund to match state PBF expenditures. Several bills with such a mechanism have been introduced in Congress.[10]

- Congress should also adopt pending tax credits on high-efficiency residential air conditioners and energy-saving new commercial buildings as a complement to the programs proposed in this report. Several bills have been introduced in Congress that call for a 10% tax credit on residential central air conditioners and heat pumps with a SEER of 13.5 or more, and a 20% tax credit on systems with a SEER of 15 or more. The proposed commercial building tax would provide incentives of up to $2.25 per square foot for buildings that realize energy savings of 30-50% relative to current model energy codes.[11]

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[10] Bills with a PBF introduced in the 106th Congress include bills drafted by Senator Jeffords (S. 1369), Rep. Pallone (H.R. 2569), Rep. Kucinich (H.R. 2645), and the Clinton Administration (S. 1047 and H.R. 1828).

[11] In the 106th Congress, bills with provisions along these lines include bills drafted by Rep. Matsui (H.R. 2380), Senator Smith (S. 2718), and Senator Roth (S. 3152).

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APPENDIX A: ECONOMIC COMPARISON OF DEMAND-SIDE AND SUPPLY-SIDE OPTIONS FOR ADDRESSING PEAK DEMAND

Measure	Incremental Cost	kW Saved	Life (years)	$/kW-yr	Notes
Supply-Side Options					
Peaking power plant (capital)			30	$47	NWPPC figures from Eckman 2000.
Peaking power plant (capital and operating)				$55	Assumes operation 3% of year, heat rate of 9847 Btu/kWh, and $3/Mbtu for gas.
Transmission upgrade	$72,000,000	240,000	30	$22	Varies widely; example given is for S. Fork on Ll as noted in text.
Local distribution upgrades				$20–60	NWPPC figures from Eckman 2000.
Energy Efficiency Options					
High-efficiency chillers	$60	0.1	30	$44	Figures are per ton of capacity from XENERGY Inc. et al. 1996.
High-efficiency commercial package air conditioner	$510	1.71	15	$31	Figures for improving a 7.5-ton unit from 9.1 to 11 EER; from NEEP 1998.
Efficient residential air conditioner	$550	0.83	18	$62	Figures for improving a 3-ton unit from 10 to 13 SEER; from Thorne, Kubo, & Nadel 2000b. Cost from Appendix C.
Residential air conditioner tune-up	$375	0.39	15	$98	Based on figures in Appendix C.
Commercial retrocommissioning	$0.20	0.0006154	7	$58	Figures per sq. ft. and based on data in Suozzo & Nadel 1998 and Appendix C.
Commercial lighting upgrade	$4	0.01404	20	$22	Figures for T8 lamps and electronic ballasts from Suozzo & Nadel 1998 and assuming 78% of lights on at peak (per Appendix C).
Commercial lighting design	$0.40	0.000312	20	$112	Figures per sq. ft. from Suozzo & Nadel 1998 and assuming 78% of lights on at peak.

Measure	Incremental Cost	kW Saved	Life (years)	$/kW-yr	Notes
Load Management Options					
Residential air conditioner load control	$250 + $26/yr	0.97	15	$53	Fixed costs of ~$200 for switch, installation, and marketing plus $50/point for the central system.
Residential water heater load control	$250 + $26/yr	0.56	15	$92	Same as above.
C&I interruptible rate				$44	Average for 1994 programs from EPRI 1995.
Note: $/kW-year is the value of one kW of generating capacity or its equivalent for a 1-year period. This measure is commonly used in power markets. We calculate this value by assuming the incremental cost is financed with a loan at a 6% real interest rate for a term equal to the measure life, and then dividing the resulting annual loan payments by the kW savings.					

APPENDIX B: ESTIMATED PEAK DEMAND SAVINGS FROM PROPOSED PROGRAMS

Program	Basecase Use/Unit	Savings	Savings/ Unit	Eligible Units/ Area	Penetra-tion Rate 2001–10	Peak Savings in 2010
	(KW)	*(%)*	*(kW)*	*(1000 units)*	*(%)*	*(MW)*
New residential air conditioner*	2.75	30%	0.825	63,147	55%	28,700
Residential air conditioner repair**	2.75	14%	0.385	60,172	30%	6,900
Commercial HVAC equipment						
Packaged systems	10.2	18%	1.8	3,150	55%	3,200
Chillers	108.8	15%	16	70	70%	800
	(Watts)	*(%)*	*(Watts)*	*(million sq. ft.)*	*(%)*	*(MW)*
Commercial retrocommissioning	NA	10%	0.77	28,498	50%	11,000
Commercial lighting upgrades	1,404	30%	0.42	43,667	50%	9,200
Commercial lighting design	1,014	20%	0.20	48,750	50%	4,900
TOTAL						64,700

* = Includes mandatory standard effective 2006.
** = ~10% of these savings overlap w/program above.
*** = Includes mandatory standard effective 2007.
**** = Includes building code standard effective 2006.

Key assumptions for the calculations include the following.

New residential air conditioning: basecase use and savings from Appendix C. Number of eligible units based on annual sales of air-source air conditioners and heat pumps less than 65,000 Btu/hour in 1999 (from ARI 2000) times 10 years. Penetration rate assumes 50% average penetration rate for good installation practices over 10 years plus average 25% penetration rate for efficient equipment during the first 5 years due to incentive programs and average 100% penetration rate during the second 5 years due to government standards.

Residential air conditioner repair: basecase use and savings from Appendix C. Number of eligible units based on number of homes in 1997 with central air conditioning or heat pumps (from EIA 1999c) plus a 3% annual growth rate through 2005 (from Neme, Proctor, & Nadel1999). Penetration rate also from Neme, Proctor, & Nadel (1999).

Commercial HVAC equipment: Basecase packaged unit is a 9 ton unit — weighted average in 1998 based on analysis of Census Bureau Current Industrial Report data (Thorne, Kubo, & Nadel 2000b) — with an energy efficiency rating (EER) of 9.2 (modestly above 8.9 minimum standard). Savings assumes 11.2 EER (modestly above CEE Tier 2). Peak savings assumes 85% of units on at time of peak, as discussed in Appendix C. Number of eligible units based on number of units sold in 1998 from *Current Industrial Reports* (BoC 1999) times 10 years. Penetration rate assumes 25% average participation for first 6 years due to incentive programs and 100% participation in final 4 years due to minimum standards.

Basecase chiller is a 200 ton unit with an efficiency of 0.64 kW/ton. Savings based on an efficiency of 0.54 kW/ton. These figures are all authors' estimates. Peak savings assumes 85% of units on at time of peak, as discussed in Appendix C. Number of eligible units based on sales in past decade from *Air Conditioning, Heating and Refrigeration News* (1999). Penetration rate from Appendix C for first 5 years and assumes 100% penetration in final 5 years due to energy code requirements.

Commercial retrocommissioning: 10% savings from Appendix C. kW savings based on average kWh/sq. ft. for commercial buildings above 50,000 sq. ft. (from EIA 1998) times 10% savings divided by 1,950 kWh/kW (from Appendix C). Number of eligible units based on CBECS data from 1995 for buildings over 50,000 sq. ft. (EIA 1998) times an 8-year growth from EIA's *Annual Energy Outlook* (EIA 1999b). Penetration rate is the authors' estimate.

Commercial lighting upgrades: basecase assumes 1.8 W/sq. ft. for buildings that have not yet upgraded their lighting (authors' estimate) times 78% of lights on at peak (from Appendix C). Savings also from Appendix C. Eligible units based on projected commercial building floor area in 2005 (from EIA 1999b) times 0.66, where the latter is the authors' estimate of the proportion of floor area that does not presently use T8 lamps and electronic ballasts (1999 California data indicates a somewhat lower percentage [PG&E 2000b] but California has been aggressively promoting efficient lighting for more than a decade). Penetration rate based on most successful programs, as discussed in Appendix C.

Commercial lighting design: basecase assumes 1.3 W/sq. ft. for new buildings (authors' estimate) times 78% of lights on at peak (from Appendix C). Savings also from Appendix C. Eligible units based on projected annual commercial floor area growth (from EIA 1999b) times 10 years. To this we added 50% of the existing floor area in 2005 (also from EIA 1999b) based on assumption that half of the floor area has its lighting changed each decade (per discussion in Appendix C). Penetration rate based on most successful commercial new construction programs, as discussed in Appendix C.

APPENDIX C: DETAILED PROGRAM DESCRIPTIONS

1. New and Replacement Residential Cooling Systems Program

Overview

This program aims to improve the efficiency of new central air conditioners and heat pumps. It promotes both the sale of high-efficiency equipment and improvements in sizing and installation practices that affect operating efficiency and peak demand. It is modeled on a similar initiative currently being implemented in a coordinated fashion by the three large investor-owned utilities in New Jersey (Public Service Electric and Gas, GPU Energy, and Conectiv Power Delivery). The long-term goal is to transform the market to one in which quality installations of high-efficiency equipment are commonplace. The program employs several key strategies to achieve this goal:

- Incentives for the sale or purchase of high-efficiency equipment for which documentation of proper sizing and installation is provided;
- Training of HVAC technicians on key elements of quality installations;
- Sales training for contractors (i.e., how to sell efficiency);
- Direct marketing to HVAC distributors and contractors through "circuit riders";
- Promotion of HVAC technician certification; and
- Aggressive consumer marketing/education campaign on key elements and benefits of efficiency.

The success of these strategies would be enhanced significantly if they were jointly implemented by utilities with adjoining service territories or if programs were implemented by other state or regional organizations. This would ensure that clear and consistent messages were sent to market actors that serve large geographic areas that often encompass more than one utility service territory (e.g., HVAC distributors). It would also enable more efficient use of program resources by spreading the costs of developing marketing and other program materials across multiple parties.

Target Market

The program targets all residential dwellings for which a new central air conditioner or heat pump is being purchased, including both existing homes and new construction. In the case of new construction, efforts to promote proper installation of high-efficiency equipment could be coupled with efforts to promote improvements in the efficiency of the thermal envelope of the building, providing even greater savings. Utilities and other program sponsors offering such comprehensive new construction programs could offer builders the option of participating in the HVAC equipment installation program or the more comprehensive program (with sufficient incentive offered to encourage as many builders as possible to choose the more comprehensive option).

Efficiency Measures

The program promotes two efficiency tiers for central air conditioners and heat pumps:

Efficiency Level	Minimum SEER	Minimum EER	(heat pumps only) Minimum HSPF
Tier 1	13.0	11.0	8.0
Tier 2	14.0	12.0	8.5

To be eligible for an incentive or any other promotion, a central air conditioner would have to meet both the minimum SEER (a measure of average efficiency over the entire cooling season) and the minimum EER (a measure of efficiency at higher temperatures typical of those experienced during utility peak demand periods in many parts of the country) for a given efficiency tier. The minimum EER requirements would be particularly important to any effort designed to substantially reduce peak demand because efficiency at high temperatures can vary significantly among equipment with the same SEER. In particular, equipment with two-speed or multiple speed operation (common at SEER 15 or above and sometimes found in SEER 14 models) generally does not produce the same savings at peak conditions as at milder temperatures. A heat pump would have to meet the minimum HSPF standard (a measure of average efficiency over the course of the entire heating season) as well as the minimum SEER and EER standards.

In addition (i.e., under either efficiency tier), documentation of proper sizing and installation of qualifying high-efficiency equipment would have to be submitted. This would include submission of Manual J load calculations, documentation of proper refrigerant levels in the system, and documentation that airflow over the coil is within the range recommended by manufacturers (i.e., between 350 and 450 CFM/ton of capacity). Documentation of proper charge and airflow could be provided through a form similar to the one at the end of this program description. An alternative could be using charge and airflow software tools similar to those currently in use in parts of California.

This additional requirement could be implemented either from the start or in the second year of the program. Many HVAC contractors would find the proper sizing and installation requirements to represent a significant departure from how they currently do business. Indeed, many would not know how to meet them. Deferring the requirements to the second year would allow the market to begin reacting to the offer of incentives, making contractors reluctant to stop participating once the proper sizing and installation requirements go into effect. It would also enable the program administrator to “warn” contractors of the new requirements, offer training on key requirements so contractors understand and are ready to meet them, and begin educating consumers on their benefits. Deferments could be particularly helpful in areas where utilities have had relatively little demand-side management activity in the residential HVAC market, where market shares for high-efficiency equipment are low, and where HVAC contractor use of key techniques for proper sizing and installation are low.

Program Strategies

The residential HVAC business is currently a low-bid business, where investment decisions are usually driven by a desire to minimize first cost. As a result, investments in both efficiency and quality — including high-efficiency equipment, proper sizing and installation, and duct repair — are the exception rather than the rule. This reality is itself a function of a variety of ubiquitous and formidable market barriers. These are summarized in Table C-1.

Table C-1. Market Barriers to High-Efficiency Residential HVAC Systems

Market Barrier	Key Issues
Customer Access to Information	• Customers often do not know that a large majority of central air conditioner or heat pump installations are improperly sized and installed. Because systems are complex, most consumers are incapable of knowing whether they got a good installation. • Some customers lack information on the energy savings that would result from installation of an efficient HVAC system. • Customers are usually unaware of the comfort, maintenance, and equipment life costs associated with improper installations.
Customer Inability to Identify Quality Contractors	• Many customers do not have unbiased sources of information. Certification programs for HVAC technicians are very new and the public is unaware that they exist. Very few technicians have taken certification tests. • Certification programs test only “book knowledge.” Some good technicians may not pass and some may pass without having good “hands-on” technique.
Lack of Well-Trained Contractors and Technicians	• Many HVAC contractors lack the sales skills necessary to “sell” efficiency. • HVAC technicians often do not have adequate training on key elements of proper sizing and installation. • No training/certification is required to operate an HVAC business.
Lack of Program Consistency	• Different utility program standards or incentives within the same state or region often creates confusion in the market about the definition of efficiency. • Distributors and contractors that serve more than one utility service territory endure hassle of ordering different equipment and/or learning different procedures for customers in each region.
Additional Cost	• Some customers do not have the capital necessary to pay the incremental cost for efficient equipment and efficient/quality installation.
Split Incentives	• In new construction and rental housing, the person making the investment decision (i.e., builder or landlord) will not be paying the energy bills.

To be successful, the program will need to address all of these barriers. Given the diverse nature of the barriers, the program will need to have several different components.

Financial Incentives

The program offers rebates for the purchase and proper sizing and installation of high-efficiency central air conditioners and heat pumps. The incentives need to be large enough to both attract consumer interest and persuade HVAC contractors to "try" proper sizing and installation techniques. Recommended incentive levels are:

Efficiency Tier 1: $300 to $400
Efficiency Tier 2: $500 to $600

These incentive amounts are consistent with those currently offered by similar programs in New Jersey and Long Island, where utilities are having considerable success in promoting both the sale of high-efficiency equipment and the use of proper sizing and installation techniques. The incentive amounts are designed to cover approximately two-thirds of the incremental equipment cost at Tier 1, with somewhat higher portions of incremental cost being covered at Tier 2. This progressive structure has proven to be effective in steering customers towards the highest equipment efficiency levels. For example, in New Jersey, nearly half of the more than 16,000 rebates processed in 1999 were for central air conditioners with Tier 2 efficiency characteristics.

Over time, as consumers become conditioned to ask and more willing to pay for high-efficiency equipment, HVAC contractors become more accustomed to selling this equipment, and sales volumes for efficient installations grow, it should be possible to reduce incentive levels.[1]

Inspections would be necessary to ensure that program standards for proper sizing and installation are met. However, every effort should be made to also use inspections as an opportunity to further educate contractors and technicians on quality installation procedures and standards.

HVAC Technician Training

The program includes a series of HVAC technician training sessions on key elements of proper equipment installation, including ACCA Manual J-based sizing, proper refrigerant charging, and ensuring proper airflow. Additional training could also be offered on duct design (ACCA Manual D) and duct sealing/repair. Efforts should be made to work with HVAC distributors, vo-tech programs, ACCA, RSES and other potentially important trade groups in both developing the curricula and

[1] For example, between 1992 and 1997 the Potomac Electric Power Company (PEPCO) reduced the rebate it offered for SEER 13 air conditioners in Maryland by nearly 50% (PEPCO 1998). Over the same period of time, the number of Maryland program participants nearly doubled (from 4,712 to 9,114 central air conditioners and heat pumps) (PEPCO 1994, 1998). Moreover, the percent of participants at the SEER 13 level increased from 8% in 1992 to 100% in 1997 (PEPCO 1994, 1998).

providing the training. This would create some critical "buy-in" for the program. Experience in New Jersey suggests that contractors are much more likely to register for training courses if they are promoted and co-sponsored by their distributors.

HVAC technicians (or their firms) would be required to pay fees for the training. However, the program administrator could offer some inducements to complete courses. For example, it could be useful to offer discounts on sizing software and/or other key tools.[2]

Sales Training

As noted above, few HVAC contractors appear to have the sales skills necessary to sell prospective customers on buying high-efficiency equipment or paying for the extra time required to do a job right. The program offers training designed to help interested contractors to improve their sales skills. EPA's ENERGY STAR® program has developed and offers a curriculum and related materials for such sales training. Although the ENERGY STAR standard for central air conditioners and heat pumps (minimum SEER 12, no minimum EER) is lower than the minimum efficiency standard promoted by this program, ENERGY STAR's sales training concepts are applicable to any efficiency standard. Other utilities have developed and are using their own sales training curricula.

Circuit Riders

One of the common attributes of successful HVAC programs has been extensive outreach to and communication with HVAC contractors (Neme, Peters, & Rouleau 1998). Outreach and communication are even more important for the program described here because of the requirements for proper sizing and installation that many contractors would not understand and others would resent. Therefore, the program should employ individuals whose sole job would be to regularly call on HVAC distributors and contractors. Their purpose would be to explain program requirements, recruit technicians for training classes, provide rebate forms and other program materials, encourage contractors to actively participate in the program, and give contractors an outlet for expressing concerns about the program. These circuit riders would be individuals who have extensive HVAC expertise so that they could address technical questions and issues raised by the trade allies with whom they are interacting.

[2] The New Jersey utilities currently offer a free magnehelic gauge to technicians who complete their two-evening course on refrigerant charge and airflow. Magnehelic gauges can be used to measure pressure drops across the coil, which, in turn, can be used to estimate airflow. Surveys of trainees suggested that few had such tools. Offering them to technicians who complete the class ensures that they leave with both the knowledge and the tools necessary to do the job right.

Technician/Contractor Certification

One of the longer-term strategies of the program is to develop and support a mechanism for helping customers identify quality contractors. This certification mechanism should have several components:

- A certification standard that addresses key elements of efficient installations, is administered by an independent 3rd party,[3] and is likely to have credibility with the HVAC industry;[4]

- A means for consumers to easily identify contractors that have met the standard (i.e., a registry of firms that have a pre-requisite number of certified technicians and meet other business requirements);

- Assistance to technicians and contractors interested in getting certified (e.g., sponsorship of and perhaps partial subsidization of training courses and certification tests);

- Quality control procedures to ensure both that contractors do not advertise themselves as certified if they are not and that certified contractors maintain relatively high standards in their work; and

- Marketing (or co-marketing) of certified contractors to consumers.

Development of an effective certification standard will be perhaps the most critical element of this effort. Program operators should work with the North American Technician Excellence (NATE) program — together with other utilities, states, and CEE — to enhance the current NATE tests so that they adequately assesses technicians' understanding of key installation procedures that affect equipment operating efficiency. Program administrators could also want to establish a "hands-on" component (or option) to the current NATE written exam, with technicians required to pass the hands-on test as a condition for being on a program's "preferred contractor" list. Finally, program sponsors would likely want to add business requirements, such as adequate insurance and/or good standing with the Better Business Bureau, to the conditions they establish for being on the certification registry they make available to the public.

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[3] This could be best done by a local nonprofit organization that has ties to the HVAC industry and a strong interest in promoting "best practices." Alternatively, such a nonprofit organization could be created to serve this need. In either case, program administrators should support these organizations financially and otherwise in the early years of program operation, with the hope that they could gradually transition to becoming self-supporting (e.g., through contractor membership dues).

[4] Any certification program must start by certifying individual technicians. However, it will also be important to certify contractor firms for which they work. This could be done, for example, by placing an HVAC contractor firm on a certification registry if at least 50% of their technicians are certified.

Consumer Marketing/Education Campaign

One of the most important factors underlying the "low-bid" nature of the residential HVAC business is that contractors do not feel consumers are demanding or willing to pay for higher-efficiency equipment or work. This, in turn, is related to consumers' lack of knowledge on both what to ask for and why they should ask for it. Therefore, efforts to educate consumers would be essential to the success of this program. The ultimate goal of the marketing/education campaign is to establish the link between energy efficiency and quality (comfort, durability, etc.) in most consumers' minds.

To begin with, the program would develop consumer education materials that summarize the benefits of efficiency (both energy costs savings and non-energy benefits such as improved comfort), explain the key elements of an efficiency system, and provide guidance on how to select a quality contractor. These materials could take several forms, including both written pieces and a brief educational video. They could also include a quality installation specification that customers could ask contractors to incorporate into their bids. These materials would be distributed as widely as possible, both to consumers who would request them and to quality contractors who would be interested in using them to help sell their services.

A variety of different marketing vehicles would be used to both alert consumers to the availability of educational materials and deliver shorter, complementary messages to consumers. The precise nature and mix of those vehicles would depend on a variety of local conditions, including customer demographics and local costs (e.g., of media placements). The options to consider would include direct mail to consumers likely to be in the market for a new central air conditioner (e.g., those living in homes built 10–15 years ago), Yellow Page ads, a dedicated internet Web site, billboards, newspaper ads, and other forms of mass media advertising.

Relationship of Program Strategies to Market Barriers

Table C-2 shows how these program strategies address each of the key market barriers to efficiency investments in the HVAC replacement market.

Relationship to Minimum Efficiency Standards

Residential central air conditioners and heat pumps are covered by minimum-efficiency standards set by DOE. The current standard, which mandates that equipment must have an efficiency rating of at least SEER 10, took effect in 1992. As of this writing, DOE is completing a rulemaking for a new standard that will likely take effect in 2006. The standard will likely be in the range of SEER 12–13 and may include EER requirements. Promotion and incentive programs could encourage purchase of efficient units before the new standard takes effect and could also be used to promote units more efficient than the standard after the new standard takes effect.

Table C-2. Intervention Strategies' Impacts on Market Barriers

Market Barrier	Intervention Strategy
Customer Access to Information	• Develop and distribute educational materials on benefits of efficient equipment/quality installations, how to select both equipment and contractors, and information customers should ask their contractors to provide to document quality work. • Provide both sales and technical training to HVAC contractors interested in providing quality service so that they could help educate consumers.
Customer Inability to Identify Quality Contractors	• Develop and promote technician/contractor certification. • Promote sales training to enable quality contractors to differentiate themselves when meeting with consumers.
Lack of Well-Trained Contractors and Technicians	• Work with trade allies to design and offer high-quality training on sizing and other elements of proper installation that require documentation as part of incentive applications. • Provide sales training to contractors (possibly through ENERGY STAR program). • Circuit riders to encourage contractors to participate in program and help address issues and questions that contractors have, particularly in early years. • Substantial incentives for efficient equipment and quality installations help encourage some contractors to "try" different approach.
Lack of Program Consistency	• Jointly develop efficiency standards, incentive levels, training offerings, marketing plans, and other key program elements with neighboring utilities/sponsors.
Additional cost	• Offer incentives designed to cover a substantial portion of incremental cost. • Education of and marketing to consumers, encouraging them to recognize and consider life-cycle costs of investment decisions.
Split Incentives	• Offer incentives designed to cover a substantial portion of incremental cost.

Key Indicators of Success

A number of different indicators should be used to gauge program success. Key among these are:

- The percent market share of high-efficiency (i.e., minimum SEER 13 and minimum EER 11.0) central air conditioners and heat pumps;
- Reductions in the average over-sizing of new central air conditioners and heat pumps;
- Increases in the percentage of new central air conditioners and heat pumps with both proper refrigerant charge and adequate airflow;
- Increase in consumer awareness of high-efficiency HVAC equipment and services;
- Number of HVAC technicians trained in key elements of equipment installation; and
- The number of certified HVAC technicians and/or contractors.

Costs and Savings Assumptions

Savings

Increasing equipment efficiency and improving sizing and installation practices that affect actual operating efficiency are the two major components of the program that would produce energy and peak demand savings. Together, these two components could reduce central air conditioner energy consumption by 35–45% and peak demand by 25–35%. The two sources of these savings each provide roughly half of the savings.[5] Savings for SEER 13 would generally be at the lower end of this range and savings for SEER 14 towards the upper end of this range. The baseline energy use to which these saving percentages would apply would vary considerably from region to region. The baseline peak demand could also vary. However, it is not likely to vary as much. On average, baseline coincident peak demand is likely to be on the order of 2.75 kW.[6] Thus a 25–35% peak demand savings would translate to approximately 0.7–1.0 kW savings per home.

Costs

The incremental cost of a SEER 13 central air conditioner is estimated to be on the order of $530-610, while a SEER 14 is approximately $640-765 (ECW 1997). There is also an incremental cost associated with the extra time contractors must take to properly size central air conditioners and perform the tasks to ensure that there is proper charge and adequate airflow. However, those costs are more than offset by the cost savings associated with not over-sizing equipment. Therefore, the incremental cost of proper sizing and installation can be considered $0.

[5] Proper sizing, charge, and airflow would save approximately 20–25% of energy use and 10–15% of peak demand, depending on whether the installation would be in an existing home or new construction (Neme, Proctor, & Nadel 1999). Increasing equipment nameplate SEER from 10 to 13 or 14 would produce energy savings of 23–29%. Increasing equipment nameplate EER to 11 or 12 would produce peak demand savings of 16–23% (assuming baseline EER of 9.2). Note that the savings from these two components are not additive (i.e., there are interactive effects).

[6] A 3 ton central air conditioner will draw 3.91 kW if it has an EER of 9.2 [kW = (Btuh/(EER*1000))]. An EER of 9.2 is typical for a SEER of 10.0. A recent study of six different utility service territories suggested that, on average, 15% of units were constantly off during the hour of system peak, 60% of units were cycling (largely due to over-sizing), and 25% of units were running constantly (Petersen & Proctor 1998). If the average duty cycle of the 60% that were cycling was 75%, the average coincidence factor for the entire population would be 70% [(0.60*0.75)+0.25]. A 70% average coincidence factor applied to an average full load draw of 3.91 kW yields an average coincident kW of 2.74.

Non-Energy Benefits

There are substantial non-energy benefits associated with efforts to promote proper sizing and installation. Chief among these are improved comfort in the home, reduced maintenance costs, and longer equipment life.

For example, a properly sized air conditioner will operate for longer periods of time — with fewer "ons" and "offs" — than an oversized unit. That improves humidity control during moderately hot days because it allows the indoor coil to get cold enough to remove moisture from the air. It also reduces stress on the compressor.

Proper airflow and proper charging are also essential to maintaining comfort. Both are necessary to permit proper humidity control. If airflow or refrigerant levels are too low, the capacity of the equipment is reduced since not enough heat transfer can occur between the coils and the air in the duct system. This can compromise the ability of the system to cool a home, particularly on very hot days. Very low airflow or too much refrigerant can lead to icing of the coils, refrigerant floodback, and even compressor failure (Neme, Proctor, & Nadel 1999; Parker et al. 1997).

Measure Life

The savings are expected to last for the life of the new central air conditioner or heat pump. That life was estimated by DOE (2000b) to be 18 years.

Possible Market Penetration Rates

Market penetration rates will likely vary to some degree depending on location. The key market barriers are likely to be more severe in some states than in others. As a result, the baseline market share for high efficiency varies from state to state. This is often at least partly a function of historical utility attempts to influence the market. For states where utilities or other organizations have previously promoted high-efficiency equipment (very few have also promoted proper sizing and installation) but where no substantial efforts currently exist, participation rates can be expected to grow as follows:

Year 1:	15% (assumes no sizing and installation requirements)
Year 2:	15% (assumes sizing and installation requirements begin)
Year 3:	20%
Year 4:	30%
Year 5:	40%

These participation rates are necessarily uncertain projections as the few program administrators that are currently operating similar programs are in only their first or second year of operation. At least one utility was able to achieve a 50% market penetration rate for SEER 13 equipment within 5 years of program operation (Neme, Peters, & Rouleau 1998). However, that was achieved without proper sizing and installation requirements.

Residential Central Air Conditioner and Heat Pump Rebate Program
Airflow & Charging Documentation Form

(Based on New Jersey Utilities rebate form)

A. PROGRAM REQUIREMENTS AND GUIDELINES

1. All applications must include a cooling load calculation worksheet consistent with ACCA Manual J procedures. The installing contractor must size the equipment within 15% or half ton of the calculated cooling load ("Manual J Calculation" or equivalent).
2. For all homes, the installing contractor must measure and document the airflow across the evaporator coil using this form. For residential new construction installations only, the contractor must also verify that the measured airflow across the evaporator coil is within 10% of the manufacturer specifications. A copy of the table or graph used to estimate airflow must be attached to the completed form.
3. The installing contractor must document the proper amount of charge installed (as determined by the manufacturer) by using one of the following charging methods: Weigh In, Superheat, Subcooling, or the Lennox Approach Method. A copy of the table or graph used to determine the proper amount of charge must be attached to the completed form.

B. PROPER SIZING REQUIREMENTS

In order to assure that the equipment installed is properly sized, contractors/installers are required to submit Manual J calculations. The calculations can be either hand-written on Manual J Form J-1 or performed with the use of a computer-based tool that is consistent with Manual J. In either case, copies of both the inputs used in the calculations and the resulting load calculations must be submitted to your utility in order for the customer to be eligible for a rebate. In reviewing the submitted sizing calculations to determine eligibility, your utility will focus particular attention on the following:

1. **Consistency between equipment capacity and sizing calculations.** Installed equipment capacity must be within either 15% or half ton of the calculated Manual J load.
2. **Indoor design temperatures.** Manual J sizing calculations must be performed with an indoor design temperature no lower than 75°F and an indoor relative humidity of either 50% or 55%.
3. **Window Areas.** The utility expects that the vast majority of sizing calculations will be conducted using actual rough window areas between 10% and 18% of floor area, with the average below 15% (in most homes, window areas are approximately 10% to 15% of the floor area. In homes considered more "open" or "stylish", window areas may be as high as 19% of the floor area. Window areas only rarely exceed 20% of floor area).
4. **Summer infiltration rates.** Manual J specifies summer infiltration rates (in Air Changes per Hour) that should be used to calculate design cooling loads. These infiltration rates are a function of the area of the home that will be cooled (in square feet) and the assumed tightness of the home ("best", "average", or "poor"). Below are the infiltration assumptions required by Manual J, including definitions of the three different building envelope conditions.

Summer Air Changes per Hour (ACH) to be Used in Manual J Calculations of Design Cooling Loads

	House Area to be Cooled (in Square Feet)			
Envelope Condition	Less than 900	901 to 1,500	1,501 to 2,100	Greater than 2,100
Best	[illegible]	0.2	0.2	0.2
Average	0.6	0.6	0.4	0.4
Poor	0.8	0.7	0.6	0.5

Source: ACCA Manual J *Load Calculations for Residential Winter and Summer Air Conditioning, Seventh Edition*

Definitions of Envelope Condition:

Best: "Continuous infiltration barrier, all cracks and penetrations sealed, tested leakage of windows and doors less than 0.25 CFM per running foot of crack, vents and exhaust fans dampered, recessed ceiling lights gasketed or taped, no combustion air required or combustion air from outdoors, no duct leakage."

Average: "Plastic vapor barrier, major cracks and penetrations sealed, tested leakage of windows and doors between 0.25 and 0.50 CFM per running foot of crack, electrical fixtures which can penetrate the envelope not taped or gasketed, vents and exhaust fans dampered, combustion air from indoors, intermittent ignition and flue damper, some duct leakage to unconditioned space."

Poor: "No infiltration barrier or plastic vapor barrier, no attempt to seal cracks and penetrations, tested leakage of windows and doors greater than 0.50 CFM per running foot of crack, vents and exhaust fans not dampered, combustion air from indoors, standing pilot, no flue damper, considerable duct leakage to unconditioned space."

C. CHARGING LENNOX SYSTEMS

If you are using the Lennox Approach Method, document your inputs and measurements in the "Option 3: Subcooling" section of this rebate form as shown in the sample below. Be sure that all shaded areas shown in the sample are completed on the actual form.

OPTION 3: SUBCOOLING Note: Typical for most Thermo Expansion Valve systems when outdoor temperature is greater than 60°F

<u>INPUTS</u>

Refrigerant type: ☐ R-22 ☐ R-410A ☐ Other (specify)

Required Subcooling: °F (from nameplate/manufacturer service guide)

Outdoor Dry Bulb Temperature: °F

<u>MEASUREMENTS</u>

Liquid line pressure psig

(F) Saturation temperature for measured pressure °F

(G) Liquid line temperature °F

Measured Subcooling (F minus G) °F

*Measured Subcooling must be within ±°F of the manufacturer specified Subcooling

Note: **Substitute Outdoor Dry Bulb Temperature for item (F) in the calculation**

Residential Central Air Conditioner and Heat Pump Rebate Program
Airflow & Charging Documentation Form

(Based on current New Jersey utilities rebate form)

Customer Name: ____________________ Application #:

Contractor Name: ____________________ Contractor Phone: ( ) __________

Contractor Mailing Address: ____________________ Contractor Signature: __________

____ ____________________ Utility: ☐ Utility A ☐ Utility B ☐ Utility C

Quality Installation: Inert gas (Nitrogen) should be used during any brazing/soldering of refrigerant lines on your installation

AIR FLOW

Rated Cooling Capacity (tons): Target Airflow Volume (CFM): ____

Total static pressure drop ("W.C." inches of water column) measured across evaporator coil if newly installed: __________

or external static pressure for fan coil unit:

Total Static Measured With: ☐ Dry Coil (Blower only, fan on cooling speed) ☐ Wet Coil (entire A/C unit operating)

Blower Fan Speed Setting: ☐ Low ☐ Medium/Low ☐ Medium ☐ Medium/High ☐ High

CFM Air Flow Estimated From Total Static Measurement: __________ Estimated From: ☐ Table ☐ Graph

Note: Copy of table or graph supplied by manufacturer and used to estimate airflow must be attached to this form.

CHARGING OPTIONS

Charging Method Used: ☐ WEIGH IN ☐ SUPERHEAT ☐ SUBCOOLING ☐ LENNOX APPROACH METHOD

NOTE: If Lennox Approach Method used, see cover for instructions on completing the charging section

OPTION 1: WEIGH IN

Refrigerant type: ☐ R-22 ☐ R-410A ☐ Other: __________ (specify)

Outdoor unit capacity: ______ pounds ______ ounces

Does this capacity include an allowance for an evaporator? ☐ Yes ☐ No

Does this capacity include an allowance for a line set? ☐ Yes ☐ No

Allowed line set length ______ feet

(A) Suction Line outside diameter ______ inches, Net length* ______ feet x ______ ounces/foot = ______ ounces

(B) Liquid Line outside diameter ______ inches, Net length* ______ feet x ______ ounces/foot = ______ ounces

(C) Driers, Accumulator, and Evaporator Capacities (if not included above) ______ ounces

*Net Length = Measured Length minus (-) Allowed Length: **Total charge weighed in** (A) + (B) + (C) ______ ounces

Note: A copy of the manufacturer's specifications for weighing in of additional refrigerant must be attached to this form.

OPTION 2: SUPERHEAT

INPUTS Refrigerant type: ☐ R-22 ☐ R-410A ☐ Other: __________ (specify)

Manufacturer Specified Superheat: ______ °F (from manufacturer service guide or as per manufacturer's specification or cut sheet)

Indoor Wet Bulb Temperature: ______ °F (near system return)

Outdoor Dry Bulb Temperature: ______ °F

MEASUREMENTS

Vapor (suction) pressure	psig
(D) Saturation temperature for measured pressure	°F
(E) Vapor (suction) line temperature near compressor	°F
***Measured Superheat** (E minus D)	°F

*Measured Superheat must be within 5°F of the manufacturer specified Superheat

Note: A copy of the documentation of the manufacturer's specified superheat for the installed equipment must be attached to this form.

OPTION 3: SUBCOOLING

INPUTS Refrigerant type: ☐ R-22 ☐ R-410A ☐ Other: __________ (specify)

Required Subcooling: ______ °F (from nameplate/manufacturer service guide or as per manufacturer's specification or cutsheet)

Outdoor Dry Bulb Temperature ______ °F

MEASUREMENTS

Liquid line pressure	psig
(F) Saturation temperature for measured pressure	°F
(G) Liquid line temperature	°F
***Measured Subcooling** (F minus G)	°F

*Measured Subcooling must be within 3°F of the manufacturer specified Subcooling

Note: A copy of the documentation of the manufacturer's specified subcooling for the installed equipment must be attached to this form.

Note: based on the NJ utilities' current forms.

2. Residential Cooling Systems Tune-Up and Repair Program

Overview

This program aims to improve the efficiency of *existing* central air conditioners and heat pumps. It promotes the retrofit treatment of common operating problems that adversely affect operating efficiency — particularly improper levels of refrigerant charge, inadequate airflow, and substantial duct leakage — by specially trained and equipped HVAC technicians. The program is modeled on a similar initiative currently being implemented by San Diego Gas and Electric with substantial assistance from the Proctor Engineering Group. This program's long-term goal is to transform the market to one in which there are a substantial number of HVAC technicians capable of diagnosing and treating HVAC efficiency problems working for HVAC firms that see sales of such services as a core part of their business. To achieve this goal, the program employs several key strategies:

- Modest consumer incentives for both assessments of HVAC systems and treatment of any problems identified;
- Aggressive marketing campaign to encourage consumers to ask qualified HVAC contractors to assess and treat potential operating efficiency problems;
- Direct marketing to HVAC contractors (through "circuit riders") to encourage them to participate in the program;
- Providing interested contractors with both easy-to-use software for guiding treatment of key HVAC operating efficiency problems and the training on how to use it;
- A quality control mechanism to ensure that any remedial work performed on HVAC systems was done properly and that any contractors submitting fraudulent data were identified and removed from the program; and
- A mechanism for referring interested customers to qualified HVAC contractors.

Target Market

The program targets all residential dwellings that currently have operating central air conditioners or heat pumps.

Efficiency Measures

The program promotes diagnosis and treatment of HVAC operating problems that adversely affect operating efficiency. It has two specific treatment "modules":

- Correction of refrigerant charge and/or airflow problems; and
- Duct sealing and repair.

Program Strategies

Numerous studies from around the country have demonstrated that most existing central air conditioners and heat pumps suffer from a variety of conditions that combine to significantly reduce their operating efficiency, degrade comfort in the home, and impose strains that could reduce the life of the equipment. For example, roughly 70% of all central air conditioners and heat pumps have inadequate airflow over the coil and/or improper levels of refrigerant. At the same time, the average duct system leaks 20% or more of the air that flows through it to or from the outdoors (Neme, Proctor, & Nadel 1999). These conditions typically persist until there's a catastrophic event (e.g., the break-down of the equipment). They are not treated during maintenance or other service calls due to a variety of ubiquitous and formidable market barriers, which are summarized in Table C-3.

Table C-3. Market Barriers to High-Efficiency Residential HVAC Systems

Market Barrier	Key Issues
Customer Access to Information	• Customers often do not know that a large majority of central air conditioner or heat pump systems are operating with a number of problems. • Some customers lack information on the energy savings that would result from treatment of these problems. • Customers are often unaware of the comfort, maintenance, and equipment life costs associated with improper installations.
Customer Inability to Identify Qualified Contractors	• Customers have no easy way to identify contractors who could effectively diagnose and treat key operating problems. Certification programs for HVAC technicians are very new and the public is unaware that they exist. Very few technicians have taken certification tests. • Certification programs test only "book knowledge." Some good technicians may not pass while some may pass without having good "hands-on" technique.
Lack of Well-Trained Contractors and Technicians	• Few HVAC technicians have adequate training on diagnosis and treatment of key HVAC operating problems, nor do they have an understanding of the benefits of treating them. This is particularly true for duct leakage. • Even if they had the training, many HVAC technicians do not have the tools necessary to accurately diagnose and treat problems.
Split Incentives	• In rental housing, the person making the investment decision (i.e., builder or landlord) will not be paying the energy bills.

To be successful, the program would need to address all of these barriers. Given the diverse nature of the barriers, the program would need to have several different components.

Financial Incentives

The program provides separate consumer incentives for testing the HVAC systems and then treating any problems identified. The incentives in the first year should be as follows:[7]

Charge/Airflow Test:	$ 25
Duct Leakage Test:	$ 75
Charge/Airflow Repair:	$ 50
Duct Sealing/Repair:	$200

These values may be modified in future years based on reactions from the market.

In addition to the customer incentives, the program should offer participating HVAC contractors and their technicians substantial discounts (e.g., 50%) on the purchase of several key tools necessary to diagnose and treat charge, airflow, or duct leakage problems.

Diagnostic Software and Technician Training

The program employs easy-to-use software — in two separate modules — to enable qualified HVAC technicians to provide either charge/airflow correction or duct sealing services.[8] To be eligible to participate in the program, HVAC technicians would have to use this software, receive training in how to use it, and have the diagnostic tools that are necessary to use it correctly.[9] Technicians also would have to work for contractors that have all necessary licenses, adequate insurance, and good standing with the Better Business Bureau.

[7] These incentive levels differ in some respect from those currently offered by San Diego Gas and Electric. For example, SDG&E currently offers $75 for a charge and airflow test, irrespective of whether corrective action is taken. This program design recommends making only one-third of that amount available for the charge/airflow test and two-thirds of it available for repair work in an attempt to place the incentive on activity that will produce savings. Similarly, the duct sealing incentive is slightly lower than SDG&E's for testing ($50 vs. $75) but higher for actual repair work ($200 vs. $125).

[8] Examples of software that could be used include Proctor Engineering's "check-me" software and Aeroseal's duct sealing software.

[9] For the charge/airflow module, HVAC technicians must have a digital thermometer, electronic scale, and quality thermocouples. For the duct sealing/repair module, contractors must have a duct blaster and monoxer.

Technician training would be largely hands-on, with trainees physically performing diagnostic procedures and repairs on several central air conditioners and heat pumps in the presence (and with the guidance) of an expert trainer. The hands-on approach to training would require very small "class sizes," with only 2 to 3 technicians participating in any given training session. Training for the charge and airflow training session would take two days (including a full day for instruction on how to correct airflow problems). Training for duct diagnostics, sealing, and repair would also take two days. Training would be offered free of charge to HVAC technicians who sign up for the program in the first year. Depending on market reaction, contractors could be asked to pay for a portion of the training in subsequent years.

Quality Control

The software employed by the program would be designed to provide some level of quality control for the user in the field by "flagging" data entries that are unlikely to be accurate and providing recommendations on how to correct problems implied by the data entered. In addition, HVAC technicians would be required to report all pre- and post-treatment diagnostic data to a program contractor intimately familiar with the software. The program contractor would also analyze the data. Such analysis would include assessment of whether any HVAC contractor is submitting fraudulent data (ideally, the software used by the program would be able to help identify patterns of data reporting that suggest "invented" data). If necessary, on-site inspections would also be conducted.

It should be emphasized that these quality control procedures are intended to do much more than catch a few fraudulent contractors or technicians. The procedures' most important function would be to provide nearly instantaneously feedback to technicians in the field on how they are performing and how they could improve their work.[10] Of course, the procedures could also serve as a means of tracking program impacts.

Outreach to Contractors

Circuit riders would be employed to regularly meet with HVAC contractors for the purpose of both recruiting them into the program, and for those already in the program, to obtain feedback on how it is working for them, identify problems being encountered ,and answer questions or address problems. The "circuit rider" function for this program could be integrated with the "circuit rider" function of the HVAC replacement program discussed above.

Consumer Marketing/Education Campaign

[10] Results fromsoftware could be reported from actual job sites over the phone. This is the way that most of the jobs in the current SDG&D program are recorded and checked (Proctor 2000; Sybert 2000).

One of the most important factors underlying the absence of a market today for charge/airflow and duct repair services is consumers' lack of knowledge of both the likelihood that they have such problems and the benefits they would realize from addressing them. This program endeavors to educate consumers on these issues and encourage them to seek out HVAC contractors who could help them diagnose and address key problems.

To begin with, consumer education materials would be developed that summarize the benefits of efficiency (both energy costs savings and non-energy benefits such as improved comfort), explain the key elements of an efficient system, and provide guidance on how to select a quality contractor. These materials could take several forms, including both written pieces and a brief educational video. These materials would be distributed as widely as possible, both to consumers who would request them and to quality contractors who would be interested in using them to help sell their services. They would be closely integrated with any educational materials developed for promotion of quality installations of new equipment under the equipment replacement program discussed above.

A variety of different marketing vehicles would be used to both alert consumers to the availability of educational materials and deliver shorter, complementary messages to consumers. The precise nature and mix of those vehicles would depend on a variety of local conditions, including the customer demographics and local costs (e.g., of media placements). Among the options to be considered would be direct mail to consumers who moved into new homes in the past 8–10 years,[11] Yellow Page ads, a dedicated Internet Web site, billboards, newspaper ads, and other forms of mass media advertising.

Contractor Referrals

To augment the program marketing and educational efforts, the program operator would refer any customer who calls and expresses interest in improving the operating efficiency of an HVAC system to the contractors who have completed program training.

Relationship of Program Strategies to Market Barriers

Table C-4 shows how these program strategies would address each of the key market barriers to efficiency investments in the HVAC replacement market.

[11] There is no evidence that duct leakage, refrigerant levels or airflow over the coil are any better in new homes than in older homes (Neme, Proctor, & Nadel 1999)

Table C-4. Intervention Strategies' Impacts on Market Barriers

Market Barrier	Intervention Strategy
Customer Access to Information	• Develop and distribute educational materials on likelihood of operating efficiency problems, benefits of correcting the problems, and how to find a contractor who has the training and tools to treat the problems. • Provide both sales and technical training to HVAC contractors interested in providing quality service so that they could help educate consumers.
Customer Inability to Identify Qualified Contractors	• Promote sales training to enable quality contractors to differentiate themselves when meeting with consumers. • Provide customer referrals to contractors who have received training through the program.
Lack of Well-Trained or Well-Equipped Contractors and Technicians	• Provide technicians with software that would make it easier to diagnose and treat problems found in the field. • Train contractors in how to use software, as well as in related technical knowledge necessary to understand systems they are treating. • Address problems in the field through instantaneous feedback and technical support. • Employ circuit riders to encourage contractors to participate in program and help address issues and questions that contractors have, particularly in early years. • Offer discounts for purchase of key tools and equipment to encourage contractors to try different approaches. • Offer consumer incentives for efficiency equipment and quality installations to help encourage some contractors to "try" different approach.
Split Incentives	• Offer consumer incentives to significantly reduce building owners' disincentive to consider quality work. • Encourage trained contractors to sell building owners on non-energy benefits — particularly longer equipment life, lower maintenance costs, and fewer tenant comfort complaints — of treating key problems.

Key Indicators of Success

A number of different indicators would be used to gauge program success. Key among these would be:

- The number of HVAC technicians who receive program training to provide charge/airflow diagnosis and repair services;
- The number of HVAC technicians who receive program training to provide duct diagnosis, sealing, and repair services;
- The number of charge/airflow repair jobs that qualified HVAC contractors sell and complete;
- The number of duct sealing/repair jobs that program-qualified HVAC contractors sell and complete; and

- Consumer awareness of the potential operating efficiency problems they may have, the benefits of addressing them, and the availability of program services.

Costs and Savings Assumptions

Savings

Table C-5 summarizes the energy and coincident peak demand savings available from the retrofit HVAC repair services promoted by the program. These savings estimates are based on a review of dozens of studies from across the country (Neme, Proctor, & Nadel 1999).

Table C-5. Energy and Peak Demand Savings from HVAC Tune-Up/Repair

Service	% Energy Savings	% Peak Demand Savings
Charge/Airflow Repair	17%	7%
Duct Sealing/Repair	10%	10%
Combo — Charge/Airflow & Duct Repair	24%	14%

The baseline energy use to which these saving percentages would apply would vary considerably from region to region. The baseline peak demand could also vary. However, it will likely not vary as much. On average, baseline coincident peak demand would likely be on the order of 2.75 kW.[12] Thus a 14% peak demand savings would translate to approximately a little under 0.4 kW.

Costs

The full cost of a service call to repair charge or airflow is estimated to average $100 (Sybert 2000).[13] The full cost of a duct system diagnosis and comprehensive duct sealing and repair is estimated to be approximately $350 (Haskell 1996). The incremental cost of each of these services would be less if they were offered as part of a regular service call (i.e., if the cost of getting to the home were already being incurred). For example, if these services were provided at the time of a normal

[12] A 3 ton central air conditioner will draw 3.91 kW if it has an EER of 9.2 [kW = (Btuh/(EER*1000))]. An EER of 9.2 is typical for a SEER of 10.0. A recent study of six different utility service territories suggested that, on average, 15% of units were constantly off during the hour of system peak, 60% of units were cycling (largely due to over-sizing), and 25% of units were running constantly (Petersen & Proctor 1998). If the average duty cycle of the 60% that were cycling was 75%, the average coincidence factor for the entire population would be 70% [(0.60*0.75)+0.25]. A 70% average coincidence factor applied to an average full load draw of 3.91 kW yields an average coincident kW of 2.74.

[13] Some of the HVAC contractors participating in the SDG&E program are offering the service to consumers for the cost of the incentive ($75) that the utility has made available.

service call, the incremental cost would be approximately $75 less than the costs noted above, after crediting the cost of a normal service call.

Non-Energy Benefits

There are substantial non-energy benefits associated with efforts to promote corrections to air conditioner charge and airflow and also to seal/repair duct systems. Chief among these are improved comfort in the home, reduced maintenance costs, and longer equipment life.

For example, both proper airflow and proper charging are essential to maintaining proper humidity control. If either airflow or refrigerant levels were too low, the capacity of the equipment would be reduced since not enough heat transfer could occur between the coils and the air in the duct system. Duct leakage also reduces effective equipment capacity, particularly if there are leaks in the attic (Rodriguez et al. 1995). Such capacity losses could compromise the ability of the system to cool a home, particularly on very hot days. Very low airflow or too much refrigerant could also lead to icing of the coils, refrigerant floodback, and even compressor failure (Neme, Proctor, & Nadel 1999; Parker et al. 1997).

Measure Life

The savings from charge and airflow corrections could be expected to last for the remaining life of the central air conditioner or heat pump. If the life of a central air conditioner can be estimated as 18 years (see previous program description), on average the remaining life of an existing unit can be estimated as 9 years.

The savings from duct sealing and repair could outlast the existing central air conditioner or heat pump. They can be assumed to last 15 years.

Possible Market Penetration Rates

Market penetration rates would likely vary to some degree depending on location. The key market barriers would likely be more severe in some states than in others. On average, it should be possible to reach the following percentages of existing central air conditioners and heat pumps over a 5-year period:

Table C-6. Penetration Rates for Residential HVAC Tune-Up/Repair

	Charge/Airflow Repair	Duct Sealing/Repair
Year 1	0.30%	0.08%
Year 2	0.75%	0.20%
Year 3	1.50%	0.50%
Year 4	3.00%	1.00%

Year 5	4.00%	1.50%

The estimated participation rates for the early years are consistent with those realized by SDG&E in its first 16 months of operating a software-based program for charge/airflow repair and in its less than 12 months of a duct sealing initiative similar to the one proposed here.[14] The rates for Years 3 through 5 are extrapolations from the first 2 years, as no similar program has progressed beyond its second year of operation.

[14] SDG&E has slightly over 1 million residential customers. Roughly one-third of them have central air conditioners (Downey and Proctor 1999). Therefore, there are approximately 350,000 residential central air conditioners in SDG&E's service territory. SDG&E's goal for the year 2000, its first full year of operation, is 3,000 charge/airflow tests (or roughly 0.85% of the central air conditioner stock). That goal will probably be met. Approximately half of those tested (i.e., a little more than 0.4% of the central air conditioner stock) are expected to receive treatment to correct problems (Proctor 2000). SDG&E also expects to have 500–1,000 duct tests performed in 2000 (Proctor 2000). If half of those result in corrective action, the program will have sealed the ducts of 0.07–0.15% of the central air conditioning systems.

3. Commercial and Industrial HVAC Equipment Program

Overview

The goal of this program is to assure the efficient selection and installation of cooling and air distribution systems in the commercial and industrial sectors. There are two primary components—chiller system efficiency and unitary HVAC system efficiency. In each case, "system efficiency" incorporates efficient equipment and proper specification, design, and installation. Utilities or other program sponsors could significantly reduce peak simply by assuring selection of efficient chillers and unitary systems, but could save much more through influencing overall system design and installation practices.

There are two major ways to capture the savings from high-efficiency cooling equipment: voluntary programs such as the Consortium for Energy Efficiency's unitary equipment standards and rebate programs, and mandatory standards. Both approaches are needed to help reduce demand.

While consumers and commercial buildings could save money by choosing efficient systems, many unitary systems are purchased based on recommendations by building contractors who have no concern with operating cost. Therefore, mandatory standards would provide the most long-term benefits. Standards for small commercial systems expected by 2003 will likely increase performance 10–20%. Setting a strong new federal standard on residential and small commercial air conditioning and heat pump systems could eliminate the need for approximately 26,000 MW of peak generating capacity by 2010, and more than twice that by 2020 (Thorne, Kubo, & Nadel 2000b). Additional savings could be achieved through building code standards on larger systems.

The proposed voluntary program focuses on marketing higher-efficiency units not only to achieve direct effects, but to influence federal standard-setting procedures and state and local codes. High near-term penetration of units that meet the Tier II standard set by CEE (discussed below) could help support a nearer-term and more stringent standard. The program could also help accelerate acceptance and state and local adoption of the chiller efficiency levels in the ASHRAE 90.1-1999 standard (also discussed below).

However, there are savings on chiller efficiency available beyond the ASHRAE standard. Furthermore, savings from system design and installation will largely be influenced by market forces because these elements are difficult to incorporate into standards. For these reasons, the program offers a system of rebates, vendor and customer marketing, technical assistance, and training designed to build market demand for efficient equipment, design, and installation and systems, and also to assure that contractors can meet that demand.

Program success would require a close working relationship with key vendors as well as customers. Implementors should work with customers so they can ascend a ladder of sophistication in HVAC system design, as described below:

Step 1. Select efficient equipment
Step 2. Monitor systems and properly size equipment
Step 3. Design efficiency into chiller distribution systems and unitary ducts.
Step 4. Reduce heat-producing loads (e.g., lighting, computers) before sizing and designing large systems.
Step 5. Employ efficient installation and commissioning practices.

While each of these elements adds complexity to the program, the utility or other program implementor could add them incrementally as technical and administrative capability is added, and customers could access the program at the level of their own motivation and capability.

Target Market

The target market consists of unitary HVAC systems (including split, heat pump, etc.) and chiller systems in all commercial and industrial buildings. Common "early adopters" for both chiller systems and unitary HVAC include owner occupants, more forward-looking institutions, and buildings with heavy cooling loads. Early participants in unitary HVAC programs have included hospitals, restaurants, some retail (especially chains), and some industrial facilities. Hospitals, universities, and industrial facilities have been early participants in programs to optimize chiller systems and related loads. In some cases, chiller optimization has actually removed production bottlenecks at industrial facilities.

The relative importance of chillers versus unitary equipment depends on local equipment stock characteristics. Areas with high-rise buildings and older buildings (pre-1990s) tend to have more chillers. Areas with more one- and two-story buildings and more recent buildings tend to have more unitary equipment. While new construction is important, HVAC equipment sales in many areas are dominated by replacement of failed or failing equipment. In most areas, 60% or more of unitary sales volume is replacement equipment. This is especially important because many replacement purchases are not influenced by building codes. Codes may theoretically apply in some cases, but are rarely enforced unless there is a major renovation. The majority of purchased chillers are also replacements.

Chiller installation can have a lead time of 6–24 months, depending on the situation. Therefore, efficiency work with unitary equipment may have more impact during the first 2 program years. However, chiller loads may cumulatively be significant over several years in high-rise cities where chillers are common. Also, chillers provide an opportunity to get large savings from each site.

The chiller optimization approach discussed below could provide significant additional savings, but generally it is only applied to a minority of the replacement chillers in a given year. This is due to the significant time and capital requirements needed.

Efficiency Measures/Incentives

Chillers involved in this program should exceed the minimum peak efficiency thresholds in the recently passed ASHRAE 90.1-1999 standard. Separate minimum thresholds for peak efficiency and integrated part load value (IPLV) are recommended. The former are more appropriate for heavily loaded chillers, and the latter for chillers that operate only partly loaded most of the time. If a chiller is oversized for peak loads (as many are), an IPLV improvement could result in savings during peak. Furthermore, some leading brands perform better on peak, while others perform better at lower load levels. Incentives that reward exceptional efficiency by either criteria would encourage both types of savings and maximize vendor participation. And both would save peak on average. An example of chiller incentives (those for Conectiv Power Delivery — Conectiv) is provided as Table C-7.

Table C-7. Sample Chiller Program Incentive Schedule — Water-Cooled Units, 300+ Tons Cooling Capacity and Larger

KW/ton	Centrifugal		Screw	
	Full Load $/ton	IPLV $/ton	Full Load $/ton	IPLV $/ton
0.64	—	—	$29	—
0.63	—	—	$31	—
0.62	—	—	$33	$29
0.61	—	—	$35	$31
0.60	—	—	$37	$33
0.59	$35	—	$39	$35
0.58	$37	—	$41	$37
0.57	$39	$35	$43	$39
0.56	$41	$37	$45	$41
0.55	$43	$39	$47	$43
0.54	$45	$41	$49	$45
0.53	$47	$43	$51	$47
0.52	$49	$45	$53	$49
0.51	$51	$47	$55	$51
0.50	$53	$49	$57	$53

Conectiv also has incentives for smaller and air cooled chillers. These incentives can be obtained at their Web site (Conectiv 2000c). Utilities in New England and New Jersey plan to update chiller incentives for 2001 to reflect the new ASHRAE standard and current practice. Since significant enhancements are expected, it will be worth checking back at their Web sites for these updates.

A complicated issue for chillers is incentives for variable speed drives (VSDs). Some manufacturers are now offering chillers with built-in VSDs. Like the mechanical improvements that lead to better IPLV performance, VSDs assure better performance at partial loading conditions, which, for oversized chillers, can include peak load. We recommend measuring chiller performance for purposes of chiller rebates without VSDs and providing a separate rebate for VSDs. This would allow manufacturers with units that are most efficient at peak loads to get a rebate for improving peak performance, and then an additional rebate for using VSDs to improve part-load performance.

Recommended minimum thresholds and incentives for unitary HVAC incentives are provided in Table C-8. The efficiency levels were established by CEE for use nationwide. The incentives were set by the Northeast Energy Efficiency Partnership's Cool Choice program and are used by utilities throughout New England and New Jersey.

Table C-8. CEE Eligibility Levels and Cool Choice Incentives for Air-Source Commercial Packaged Air Conditioners

Cooling Capacity	Required Efficiency			NEEP Incentives ($/ton)	
	Federal Standard	CEE Tier 1	CEE Tier 2	CEE Tier 1	CEE Tier 2
<65,000 Btu/hour	10 SEER	12 SEER	13 SEER	$55	$85
65,000–134,999 Btu/hour	8.9 EER	10.3 EER	11 EER	$38	$68
135,000–240,000 Btu/hour	8.5 EER	9.7 EER	10.8 EER	$43	$73
>240,000	None	9.5 EER	10 EER	$43	$73

Separate thresholds and incentives have also been developed for heat pumps, packaged terminal units, and other less-conventional unitary systems. A complete set of unitary HVAC replacement qualifying levels and incentives (along with another example of chiller incentives) can be obtained as an Adobe Acrobat file from National Grid's Web site (National Grid 2000a). National Grid is a participating utility in the Cool Choice program.

As of this writing, the Tier II incentives for air-cooled systems are particularly important. As of this writing, DOE is holding proceedings to determine future efficiency standards for commercial unitary equipment. It appears likely that in a few years, units at least as efficient as Tier I will be required by law. Higher sales of Tier II units through programs might help influence DOE to set the efficiency standards higher. Tier II units are currently available in all sizes from at least two major manufacturers, and will be from a third major manufacturer by the end of 2000.

Economizers generally are not used during peak hours, but they can sometimes minimize peak loads by taking in cool morning air prior to peak. This depends on local peak hours and weather patterns. In areas with appropriate weather patterns, additional incentives should be offered to encourage enthalpy economizers and economizers with more reliable electronic controls. While many HVAC units are currently sold with economizers, enthalpy economizers are less common, some enthalpy economizers use nylon sensors which fail frequently, and dual enthalpy economizers are relatively rare. Enthalpy economizers, which account for both outside air temperature and humidity, offer significant efficiency advantages in humid climates and even in arid climates with heavy dew during early morning hours when economizers take in air. Dual enthalpy economizers optimize outside air based on comparing wet bulb temperature inside and outside the building. Additionally, most single enthalpy economizers can be set to a "minimum outside air" mode that assures contractors that there will not be callbacks, but does not provide much savings. Dual enthalpy economizers do not have this option, so are not as likely to be effectively disabled by contractors who want to avoid callbacks.

A wholesale source (who chooses not to be quoted) suggested that the retail cost of moving from a dry bulb economizer to dual enthalpy with electronic controls should cost less than $300, and to single enthalpy should cost less than $150. Retail sources (which likewise cannot be cited) suggest that incremental costs are on the order of $200 for single enthalpy controls and $400 for fuel enthalpy. It would probably be worthwhile to investigate local prices before setting incentives.

Additionally, some utilities offer incentives for chiller system optimization. These are discussed in the "Chiller Optimization" box below.

Program Strategies

Barriers to efficient HVAC systems are diverse because customers are diverse, and the demands of different elements of this strategy on customers, designers, and contractors vary. Table C-9 presents a basic overview.

Table C-9. Market Barriers to Commercial and Industrial HVAC Efficiency

Market Barrier	Key Issues
Customer Access to Information	Many customers: • Do not know that equipment choices have significant impacts on efficiency and utility costs. • Do not know much about quality installation practices, duct design and materials, economizers, or controls. • Are not aware that well-designed HVAC systems meet user needs better. • Do not have unbiased sources of information. It is difficult for customers to discern which contractors are expert in these areas.
Customer Organizational Barriers	• Most unitary systems are bought from a single contractor without competition or by low bid. Neither situation provides the contractor with high motivation to sell more expensive systems. Efficiency levels are sometimes included by customers in chiller bid specifications, but rarely for unitary systems. • Many customer organizations (small and large) have not assigned responsibility to an individual to pursue efficiency. This hampers decisions and limits expertise. • Most customers do not have the capability to perform quality assurance on duct design, chiller system design, installation, etc. • Many businesses and government entities consider energy efficiency to be a low priority for funding because it is a small part of operating costs. Many financial managers focus on maximizing revenue as a higher priority than cutting costs.
Trade Ally Barriers	• In some regions of the country, high-efficiency packaged equipment is not routinely stocked and is a "special order" item with longer delivery times and higher costs. • Many vendors have limited knowledge of efficient equipment and installation options. Customers are not providing them with the motivation to learn. • Skills to optimize chiller systems involve metering, modeling, and system design. Engineers tend to specialize in a subset of these areas. Because customers have not demanded a synthesis of these skills, nor detailed design for efficiency purposes, very few engineers have the experience to deliver. • Manufacturers' representatives often play a key advisor role in chiller selection. They may bring their own agendas and biases into the fray, based on what equipment their firm most profitably sells.
Design Methods and Values	• Most unitary systems are installed at the time of failure or when systems are performing inadequately. This allows no time for design. Generally the only trade ally consulted is the contractor. • In the absence of metered data, engineers usually add multiple "safety factors" in sizing. This results in oversized systems that could add to peak loads. • In the absence of system modeling, chillers and HVAC distribution components are not optimized.
Product Definition	• There is no nationally accepted definition for a high-efficiency chiller beyond the ASHRAE code (which is not aggressive) • While CEE provides efficiency guidelines for unitary HVAC equipment, these are not promoted in many parts of the country. • There are no well-known labels or third-party-endorsed checklists to help customers ask for quality installation, or for vendors to promote it. • There is no clear market label for a reliable, predictable product. Everything hinges on the reputation of the individual firm.

Market Barrier	Key Issues
Financial Barriers	• Efficiency improvements are often “value engineered” out of construction projects to assure that funds are focussed on more visible equipment and more immediate problems. • In rental buildings on short-term leases where the tenant pays energy bills, neither the landlord nor the tenant has a long-term interest in reducing energy costs. • In large organizations such as state and federal governments and multi-site corporations, the corporate unit that pays for construction often is not the unit that pays energy bills, and the two do not communicate effectively about management of costs. • Failed unitary equipment is often an unplanned and unbudgeted event. • Chillers are major investments. Without outside encouragement, customers will not plan for additional costs associated with chiller optimization.

The following program elements are the core of the HVAC program.

For Chiller Systems

Essential

- Rebates for chillers designed to capture currently available savings, marketed directly to customers and through vendors.

Would Significantly Add to Savings

- Metering and analysis service to help customers “right-size” chillers.
- More sophisticated incentives and technical assistance to help customers optimize chiller systems against loads (see box below).
- Workshops to help customers plan in advance for the cost and effort of optimizing chiller systems, decide when chiller operation and maintenance (O&M) exceeds amortized cost of a new chiller, and manage coolants.
- Commissioning of chiller systems.

Unitary

Essential

- Rebates tied to CEE’s unitary HVAC standards, targeted to help encourage stringent federal standards for commercial and industrial unitary equipment.

Would Significantly Add to Savings

- Complimentary rebates for efficient economizers and thermostats.
- Technical assistance and training to enhance duct design.
- Customer and contractor information to encourage efficient installation.
- Commissioning for larger buildings with multiple or large unitary systems.

The key elements are discussed in more detail below.

Chiller Optimization

Chiller optimization is the process of developing the most efficient chiller system that's possible and the best match between chillers, controls, and loads. It is recommended for utilities and other sponsors that have the technical resources to push the HVAC engineering community to higher levels of efficiency in design. National Grid has one of the most highly evolved and successful programs for chiller system optimization — Comprehensive Chiller Track, which serves 6-8 replacement chiller systems per year. This is only a fraction of the chillers addressed through National Grid's programs in a year. Most chiller efficiency projects involve only a rebate for an efficient chiller and sometimes one or two related items (e.g., a motor or variable speed drive). However, optimization projects result in very large savings per site and provide many benefits to customers, including downsizing of chillers, which could directly reduce peak kW.

National Grid pays rebates for efficient chillers (similar to Conectiv's rebates cited above), 90% of the cost of enhancements to peripherals (pumps, fans, motors, ducts, pipes, and controls), and 90% of the full cost of heat-producing loads that are made more efficient prior to the design of the new chiller system (primarily lights), or less if that is sufficient to provide the customer with a 1-year payback based on energy costs. Payments for peripherals and lighting tend to average about 65–70% of the cost of these improvements (Keena 2000). While these payment levels are high, they have proven useful in persuading customers to undertake the expense and effort of improving all components of the chiller system and heat loads at once.

For analysis of chiller optimization , hourly load data must be collected on the old chiller system. This data would then be used to create a calibrated hourly simulation of the building. This simulation would be used to model efficiency improvements to lighting and other heat-producing end-uses, then optimization of the HVAC distribution system, and finally, selection of the most efficient chiller of the correct size.

To provide an example of chiller optimization, Worcester Polytechnic Institute (WPI) in Massachusetts replaced a 290 ton 0.85 kW/ton chiller with a 170 ton 0.62 kW/ton chiller (Gartland and Sartor 1998). The chiller downsizing reduced the cost of the new chiller and was achieved in part due to reduced heat gains from installing more efficient lighting and in part due to the fact that the old chiller was oversized. At the same time, WPI installed new air handling unit controls (to improve system operation), added ASDs to pumps in the system, and installed an outdoor air heat exchanger for wintertime computer room cooling. The total project reduced electricity use in buildings served by the chillers by more than 15% and had a 5.2 year payback to WPI.

To avoid paying for measures that are common practice, the utility or other program sponsor must establish a baseline for chiller system design. This is the set of typical chiller design practices employed locally. Most program sponsors establish these practices through discussions with designers and vendors and review of recently constructed chiller systems.

Pacific Gas and Electric has developed Cool Tools as a streamlined technical approach to optimizing chiller systems. Cool Tools products are software programs, publications, and support services that together provide an objective analytical method for comparing alternative strategies during the design and operation of chilled water systems. The products are public domain and Internet-based (PG&E 2000a). As of mid-2000, over 20 modules (software and/or written materials addressing specific topics) were up and running, and more are in preparation. However, work on actual customer buildings with the tools is just beginning.

Chiller optimization programs work best if there is advance marketing, through workshops, to educate customers not only about the benefits, but about the planning requirements and the types of assistance that program sponsors can provide.

Chiller optimization can be very cost-effective to the utility. A joint filing by New Jersey utilities including a planned chiller optimization program utilized an average program cost of 1.4 cents/kWh saved over the measure life of the project (New Jersey Utilities 2000). This includes the customer share of incentives but does not include the cost of the baseline (inefficient) chiller, and was based on prior experience at other utilities.

Technical Assistance

For unitary systems in new construction and renovation, it may be possible, through utility-funded technical assistance, to encourage quality load calculations to assure proper sizing, designer specification of quality economizers, proper duct design and thermostats, etc.

Technical assistance supporting prescriptive chiller rebates can be relatively simple, but smart customer advice and active assistance can pay. For example, use of load research data or loan of a meter may make it possible to assess loadings on existing chillers prior to purchase of a new system. This load data may lead to "right sizing" a chiller. A properly sized chiller may save peak because it would operate at optimal efficiency on the peak day. Furthermore, it may not continue to "ramp up" loads if weather conditions exceed design conditions.

For replacement of unitary equipment, technical assistance is generally minimal due to the limited timeframe for purchase decisions. It is at least theoretically desirable to require load calculations for unit replacements to assure properly sized replacement units. However, the time frame for replacement and circumstances make this approach difficult. Even if smaller units are appropriate, they sometimes require expensive and time-consuming curb modifications. Furthermore, requirements to properly size equipment may reduce contractor margins. For this reason, at least until programs are well-accepted by vendors, initiatives to assure quality sizing and installation should utilize "carrots," such as technical and promotional support for premium contractor practices, rather than the "stick" of requiring good installation practices to receive equipment rebates.

Marketing

Different parties play more central roles for marketing various aspects of the program, as shown in Table C-10.

Table C-10. Role of Different Parties in Marketing Efficiency C&I HVAC Products and Services

	Contractors	Designers	Large & Multi-Site customers	Other Customers
Efficient unitary equipment sales	Critical marketing channel	Important for new construction	Direct contact is important	Reach through contractors
Unitary duct design (new buildings)	Critical participant	Critical participant	Critical participant	Participant
Unitary installation	Direct contact is important	NA	Direct contact is important	Secondary target market
Chiller efficiency	Critical marketing channel	Important for new construction	Direct contact is important	Reach primarily thru contractors
Chiller right-sizing	Can sometimes influence design	Critical participant	Critical participant	Critical participant
Optimize chiller system, optimize against loads	Secondary participant	Critical participant	Critical participant	Critical participant

Unitary sales are heavily influenced by contractors and vendors. The best marketing approach for vendors would involve consistent rebates and promotion across all program sponsors in a region. For example, Northeast Energy Efficiency Partnerships has contracted for "circuit riders" to visit vendors and provide promotion for their unitary rebate program (NEEP 2000). Additionally, for new buildings, it is important to work with customers, designers, and developers to promote efficient units. Under the NEEP program, utilities mostly work directly with customers to compliment the circuit rider's efforts with contractors. However, it may be more practical in some cases for marketing contractors to work with both parties in tandem. Conectiv Power Delivery of New Jersey, a NEEP program member utility, uses this approach.

Unitary installation would be best influenced by working both with contractors and customers to promote a set of efficient practices. While experience in this area is limited, as of this writing NEEP is experimenting with a set of customer education materials on this topic. These materials will help explain why it is important to hire a contractor who follows quality installation practices and what those practices are. A group of New Jersey utilities is also working to develop contractor training installation practices (Linn 2000). Because there is little understanding of the relationship between installation quality, efficiency, and performance among customers and contractors, program sponsors could need to take a leadership role in working with contractors to demonstrate quality practices and show the benefits.

Unitary HVAC contractors across the country have become leery of utilities because some electric utilities are buying unitary contractors and competing directly for customers. For this reason, utilities would need to assure contractors that they would not use customer data or other intelligence gathered through efficiency programs for their own purposes. However, this situation also creates an opportunity. To survive, unitary HVAC contractors are increasingly receptive to the idea of premium services as a tool to differentiate themselves in the market. A "premium contractor program," endorsed by utilities or other program sponsors as a group, could consist of promoting the use of high-efficiency equipment and high-quality controls and economizers (e.g., programmable thermostats, dual enthalpy economizers), and the adherence to a list of quality installation practices.

Chiller sales are heavily influenced by manufacturers' representatives and distributors. Some highly successful programs market efficient chillers primarily by setting up relationships with these parties. However, larger and more sophisticated customers (some chains, property managers, multi-site office and retail owners, some hospitals, and large institutions) often play a more significant role in product selection and would need to be marketed to as well.

Financial Incentives

These were discussed under "Measures," above.

Financing

Financing is particularly important for chiller optimization projects due to the significant capital cost. The type of financing referral system discussed under the lighting retrofit acceleration program (later in this appendix) is recommended.

Quality Control

For equipment rebates, the utility would need to review the proposed equipment (proposed specifications in advance where possible,[15] installed equipment after the fact) to confirm that it meets program standards. For all equipment, inspections to verify that the specified equipment is installed would be also important. We recommend that efforts to assure proper unitary equipment installation be carefully crafted to not sabotage efforts to enlist vendors. Given the delicate relationships between

[15] Because unitary equipment is often replaced under emergency circumstances, it is important that the program permit rebates without pre-inspection as long as equipment qualifies.

vendors and utilities discussed above, programs should focus on education and marketing for some time before installation quality becomes a program requirement.

Expert engineering review is important to assure that any studies of metered data to help size systems are properly done.

Relationship of Program Strategies to Market Barriers.

These relationships are summarized in Table C-11.

Table C-11. Market Barriers and Strategies for Commercial and Industrial HVAC Efficiency

Market Barrier	Intervention Strategy
Customer Access to Information	• Educational materials and promotion for customers explaining equipment efficiency, system performance, design, project planning, and installation.
Customer Organizational Barriers	• Program sponsors (staff or technical contractors) reduce the burden of recommending strategies and quality control. • Development of model bid specifications for efficient equipment. • Education for customer regarding how to identify quality contractors.
Trade Ally Barriers	• Training on efficiency economics, equipment choices, duct design, and installation practices. • Help for contractors using efficiency to differentiate themselves in the market. • Customer promotions to create the "market pull" to engage contractors. Start with the largest and most motivated customers. • Use of unitary rebate program to encourage stocking. • Use of technical studies and quality control to bring design contractors and energy specialists to the next level of capability.
Design Methods and Values	• Promotion of case studies that show quality design paying off. • Working closely with manufacturers of chillers to influence toward efficient designs. • Use of metered information to improve engineer confidence in appropriately sized systems.
Product Definition	• Promotion of the CEE Tier II unitary HVAC standard. • Development and promotion of the minimum efficiency standards for chillers. • Development of utility-endorsed unitary installation checklists. • Development of specification and/or certification for quality commissioning.
Financial Barriers	• Rebates — prescriptive and custom. • Financing referral service for large projects. • Promotion of successful jobs with bottom-line oriented case studies. • Financial planning as a key element of chiller planning workshops. • Where practical, promotion of equipment downsizing as capital savings. • Promotion of life cycle costing, but don't expect customer tendencies to focus on first cost to change overnight.

Key Indicators of Success

- Sales of efficient chillers and unitary equipment as a proportion of total sales. For unitary equipment, stocking and sales of Tier II unitary systems would be particularly important.
- Contractor and customer awareness of efficiency issues, including efficient design and installation.
- Contractors who market themselves as "premium service" contractors while adhering to utility-approved equipment selection and procedures.
- Proportion of chiller systems being optimized during design.
- Proportion of chiller systems and large unitary systems commissioned.

Cost and Savings Assumptions

Savings

Efficient chillers are available that exceed the baseline peak efficiencies shown for Conectiv's program (Table C-7) by 5–20%, depending on the size, type, and brand. Comprehensive chiller optimization generally results in greater savings, typically resulting in *additional* savings of around 10% or more (Wolpert et al. 1994). CEE Tier I unitary HVAC units reduce energy use by approximately 10% relative to typical non-qualifying units, varying with size. Tier II units save an additional 6–13%, varying with size and manufacturer. Given that efficiency is rated for peak operation, the savings should translate directly into peak savings.

Savings from economizers vary significantly from site to site. Additionally, these measures do not always reduce peak use. Economizers bring air into buildings during cool hours, which in some climates occur in the morning of peak days. This is especially true in moderate, dry summer climates where cool mornings can be followed by peak heat. Economizers that fail in the open mode significantly increase peak load. Experts differ regarding whether such failures are often noticed and corrected, but there is limited information to support any position on this topic. Economizers that fail in the closed mode can also add to peak. If installation of higher-quality economizers results in avoiding failure in a modest share of units, the energy savings would be significant and the peak savings would be significant in many climates.

When comparing savings to cost, it is important to consider the benefit of energy savings as well as peak savings. These depend on hours of use, time of use, and local electric rates.

Cost

For chiller rebates, incentives are paid per kW/ton, so cost/kW can be derived directly from the incentive chart. For example, if a 300 ton chiller were purchased at 0.54 kW/ton instead of 0.60, the cost would be $45/ton for 0.6 kW/ton, or $750/kW. Assuming that the average chiller operates at 85% of capacity during peak (and assuming conservatively that savings are proportional to loading), this would be $882/kW.

For unitary equipment, kW savings at full load can be estimated using the formula:

Peak kW= Btuh/EER/1000
Where:
Btu/hour = tons*12,000

Depending on local conditions, some unitary equipment runs at less than full load during utility peak hours because the equipment is oversized or not in use. A 85% loading factor may be reasonable (as discussed above, 70% is typical in residential but commercial average loading is higher). For example, for a 7.5 ton unit, if local common practice were the federal standard of 8.9 EER, the more efficient equipment would cost $311/peak kW.[16]

Local baseline sales patterns should be considered; many areas probably sell a mix of equipment including some at the CEE Tier I standard and some less efficient. Administrative costs should be added to this figure (perhaps 20%, depending on program design and volume).

Non-Energy Benefits

Well-designed HVAC systems tend to meet user requirements better, because the cooling system is better tailored to building requirements. Chiller optimization can often lead to reduced chiller size and consequent reduced capital costs.

Measure life

According to the *ASHRAE Handbook* (ASHRAE 1999), rooftop air conditioners have a median service life of 15 years and packaged chillers have a median service life of 23 years for centrifugal and absorption units and 20 years for reciprocating units.

[16] Peak kW = 7.5*12,000/(8.9*1000)*((11-8.9)/11)*.85=1.64 kW. The incentive suggested in Table C-8 is $68/ton, providing a cost of $311/utility peak kW.

Market Penetration

Penetration rates for efficient equipment, as a share of the units sold each year, are estimated in Table C-12. Bear in mind that this is a generalized projection based on market potential and early field results from existing programs. Anecdotal information indicates that baseline penetrations vary significantly by region. "Before-program" penetration rates should be assumed to be static over the forecast period, except for Tier II unitary equipment, where a "without program" projection is provided. The penetration rates shown are *market shares*, including nonparticipants.

For unitary equipment, the net increase in penetration would likely include a significant number of nonparticipants who have been influenced by the program (perhaps half, depending on how the program is marketed.). It is less clear whether nonparticipants would be influenced by chiller rebates. This depends on existing baselines and design practices.

Table C-12. Unitary HVAC, Chiller Efficiency, and Chiller Optimization Penetration Rates

Year	Unitary Tier II*		Chillers	Chiller Optimization
	Without Program	With Program		
Before	15%	15%	5%	0%
1	18%	20%	10%	5%
2	21%	30%	30%	10%
3	24%	40%	50%	15%
4	25%	50%	70%	20%
5	25%	50%	70%	25%

*Assumes significant base year natural market penetration. A 1998 study showed 7% penetration of Tier II equipment in the Massachusetts market in 1998, and availability of Tier II equipment has increased significantly since then (RLW Analytics 1999). Rebate programs help change the market, but many of the influenced customers do not collect the rebate.

These penetrations apply to chiller and unitary equipment *sales*, not to the existing stock. We estimate that, in 5 years, in regions with an even distribution of equipment ages over the measure life and a 4% annual growth rate, sales will equal 44% of the existing stock of chillers and 55% of the existing stock of unitary HVAC equipment.[17]

These proportions will vary locally depending on the predominant age of existing system. For example, if there was a boom in unitary installation 15-20 years ago, there will be a boom in replacement sales about now.

[17] Chiller turnover = 5 years/23 year life = 22%; chiller growth = 1.04(5th power)-1 = 22%, while 22%+22% = 44%. Unitary turnover = 5 years/15 year life = 33%; Unitary growth = 1.04(5th power)-1 = 22%, while 33% +22% = 55%.

4. Commercial Building Retrocommissioning and Maintenance

Overview

The goal of this program is to promote widespread retrocommissioning and proper ongoing maintenance of large commercial buildings. This program also seeks to build a sizable ongoing local market for retrocommissioning services by addressing the major barriers that hinder retrocommissioning today, particularly the limited number of qualified commissioning engineers and the fact that most building owners and managers are unaware of the benefits of commissioning services. Furthermore, the program seeks to maintain the savings from commissioning over time by training and certifying building maintenance staff in good building operations and maintenance procedures. The program combines training and technical assistance for building owners, managers, maintenance staff, tenants, and commissioning providers with local demonstration projects and other promotions as well as financial incentives to reduce the cost of commissioning services. Key program strategies are discussed below and include:

- Education for building owners and facility managers;
- Local demonstration projects and case studies;
- Establishing a benchmarking system to help building owners assess the performance of their buildings relative to other buildings;
- Active marketing to building owners and managers;
- Defining key services so they would be easier to understand and market;
- Commissioning service provider training and technical assistance;
- Maintenance staff training and certification; and
- Financial incentives to reduce the cost of commissioning services.

In addition, the following recommended strategies complement the above-listed activities and would contribute to the success of the program:

- Local market research;
- Tenant education to encourage tenants to talk to their property managers about workspace quality; and
- Cooperation with other commissioning programs around the country on the development of additional commissioning-related procedures and tools.

Target Market

The prime market for this program, at least in its early years, would be large commercial buildings, over approximately 100,000 square feet in size, with an emphasis on owner-occupied buildings and

Class A leased space. Owner-occupants should be targeted because they generally care the most about building energy use since they pay the energy bills and not a tenant. They are also generally more interested in making investments in their buildings. Class A offices should be targeted because they have the highest rents and maintaining tenant satisfaction is important for keeping occupancy rates and rents high. Large buildings (as well as multiple smaller buildings on common campuses) should be targeted because these buildings generally have complicated HVAC and control systems that could usually benefit from commissioning. Also, large buildings use large amounts of energy, providing opportunities for large energy and cost savings in a single project. And large buildings often have in-house maintenance staff, providing greater opportunities to maintain the savings over time. Eventually, medium-size buildings (50,000–100,000 square feet and possibly even smaller) could be targeted, but initial efforts should target large buildings.

Efficiency Measures

The prime measure to promote would be retrocommissioning services. Retrocommissioning is an event in the life of an existing building that systematically looks for opportunities to improve and optimize a building's operation and maintenance. Retrocommissioning seeks cost-effective ways to improve functionality of existing equipment and systems, and optimizes how they operate in order to reduce energy waste, extend equipment life, and improve building operation and comfort (Haasl and Sharp 1999).

Retrocommissioning is typically done by a skilled engineer with extensive trouble-shooting and commissioning experience. The commissioning process typically includes four stages — planning, investigation, implementation, and handoff (Haasl and Sharp 1999). The planning stage includes identifying project objectives and systems to be targeted, defining tasks and responsibilities, and preparing a plan that could be used to procure the desired services. The investigation stage includes on-site assessments and testing, including a review of energy use data and maintenance procedures, walk-throughs of the site (during both the day and night), and short-term monitoring of key systems. The investigation phase leads to identification of deficiencies in system operation and maintenance and the development of recommendations to correct these deficiencies. The implementation phase includes implementation of most no- and low-cost recommendations as well as development of a plan for implementing additional improvements over time. Finally, the completed improvements are "handed off" to the owner and their staff, along with information and knowledge gained during the process to help the owner and staff better maintain their building in the future.

In addition, the program promotes training of building maintenance staff on good operations and maintenance procedures. Such training could result in direct energy savings as staff identify and implement improved building management practices (details on many of these procedures can be found in Herzog 1997). Trained personnel are also in a much better position to keep building systems optimized, helping to maintain commissioning savings.

Program Strategies

Several market barriers presently hinder the commissioning of existing commercial buildings. These are summarized in Table C-13.

Table C-13. Barriers to Retrocommissioning

Market Barrier	Key Issues
Customer Access to Information	• Few owners and managers are familiar with commissioning services and their benefits. • The value of commissioning services has not been demonstrated enough to satisfy some owners and managers; some perceive that the claims are too good to be true.
Shortage of Skilled Contractors, Staff, and Tools	• Experienced staff and outside service providers are few in number. • Training for engineers and building staff in commissioning-related activities is often not readily available. • The limited size of the current market for commissioning services makes many potential service providers reluctant to get the training and experience necessary in order to enter the business. • Commissioning-procedures and software tools tend to be custom-developed by each commissioning specialist with the result that many tools are not user friendly and there is much overlap of effort.
Customer Difficulty Identifying Quality Contractors and Staff	• Managers often do not know how to locate experienced staff or outside providers nor can they identify which staff and service providers are well qualified to do commissioning work.
Split Incentives	• In rental spaces, tenants often pay energy bills, reducing the incentive for building managers to properly commission their buildings. • Tenants are unfamiliar with building optimization approaches that could improve the quality of building space as well as reduce operating costs. • Even in owner-occupied spaces, internal accounting practices, such the separation of energy, maintenance, and capital budgets, makes it difficult to obtain funds for new services or to provide direct financial benefits to those who agree to finance these services out of their budget.
Lack of Time and Institutional Inertia	• Lack of time, short-planning horizons, and institutional inertia makes it difficult for owners and managers to consider new approaches.

Program strategies seek to address these barriers in order to:

- Motivate the building owner and their staff to act;
- Make expertise to optimize building operations readily available; and
- Institutionalize the building optimization and maintenance process so that savings continue over time.

The relationship between the different barriers and strategies are summarized in Table C-14. Each of the program strategies are discussed further in the sections below.

Table C-14. Relationship Between Retrocommissioning Barriers and Program Strategies

Market Barrier	Intervention Strategy
Customer Access to Information	• Introductory workshops for owners and managers on commissioning and its benefits • Marketing to owners and managers • Local and owner-specific demonstration projects • Establish benchmarking system to help owners compare their buildings to other buildings
Shortage of Skilled Contractors, Staff, and Tools	• Commissioning service provider training • Technical assistance to local service providers by leading commissioning experts • Training and certification for building maintenance staff • Cooperation with other commissioning programs on the development of improved procedures and tools
Customer Difficulty Identifying Quality Contractors and Staff	• Educational workshops for and marketing to building owners and managers • Certification program for trained and qualified building maintenance staff
Split Incentives	• Financial incentives to reduce the cost of commissioning services • Educational materials for tenants on the benefits of building optimization
Lack of Time and Institutional Inertia	• One-on-one marketing efforts • Financial incentives to reduce the cost of commissioning services

Owner/Manager Education and Marketing

Education for building owners and facility managers is needed to familiarize these decision-makers regarding the opportunities for and the benefits of commissioning, and to provide information on how to obtain quality services. These efforts should generally target the person with budget authority for a building. A potential marketing strategy would be to emphasize how, for many buildings, building operation is a multimillion expense that is largely unmanaged. To support education efforts, standard materials would be useful such as written materials, case studies, and slide presentations (including short, medium, and long versions for different levels of decision-makers). Much of the marketing would need to be done face-to-face with individual decision-makers or through building owner associations and peer groups. One general approach that has been effective is to identify one site or system to optimize, monitor performance before and after optimization, and use the results to help convince decision-makers to optimize other systems or buildings. Utility/government endorsements could also be useful, as could be referrals to qualified contractors. Both the Building Commissioning Association (BCA) and the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) have developed one-day training programs for building owners and managers that could be adapted for use in different regions of the country (Doyle 2000; York 2000).

Local and Owner-Specific Demonstration Projects

While some case studies have been compiled, these cover only a few regions of the country. Local programs should utilize local demonstrations and case studies to help promote optimization in their local areas. In compiling these case studies, in addition to standard information on costs and energy savings, it would be useful to document non-energy benefits of retrocommissioning such as O&M cost savings or changes in worker comfort and productivity. Furthermore, for many building owners, the most relevant demonstration would be one in their own facility, or short of this, a competing firm in the same industry and market. An effective promotion technique would be to work with owners of large or multiple buildings and undertake a pilot project in one of their facilities, so they could see the benefits directly.

Establish Benchmarking System

Building owners want to know how their buildings compare to other buildings. A benchmarking system that is easy to use and adjusts for major climatic and operations differences would be a useful tool for comparing buildings and by extension, motivating owners of subpar buildings to improve their operations. EPA is working on this issue through its ENERGY STAR Buildings™ program. As of this writing, ENERGY STAR has developed benchmark tools for offices and schools, is working on a tool for retail buildings, and is developing plans for tools on several other building types. Local program managers should run several local buildings through these tools in order to validate these benchmarks for use in local programs. Another database to tie into this effort would be the Building Owners and Managers Associations's (BOMA) Experience Exchange reports.

Commissioning Service Provider Training

Many HVAC and controls engineers have experience in designing and troubleshooting building systems. However, design experience and systems operation experience are different things. Furthermore, many engineers have limited experience in using observed and metered data together to solve problems. Likewise, engineers may know how to troubleshoot problems, but are unfamiliar with how to set up procedures so that building managers can prevent problems from recurring. Still, with proper training and experience, many of these practitioners could progressively become commissioning service providers. In order to assist this process, the program should sponsor training programs for service providers — including HVAC consulting engineers, control specialists, and others — and then offer them technical assistance for their first retrocommissioning projects using experienced commissioning providers that the program would hire on a retainer basis. These experienced providers would also conduct quality control reviews on initial retrocommissioning projects.

Training programs should be a week long and include hands-on field experience. Training courses of this type have been developed by BCA and ASERTTI. Following completion of the training program, trainees would begin to market their services, but would receive free technical assistance and quality control reviews on their first few commissioning projects in order to help them gain knowledge and experience with practical commissioning procedures and trouble-shooting. Technical assistance would include assistance with preparing the commissioning plan, developing a short-term metering plan, analyzing meter and other data, reviewing draft reports, reviewing draft customer O&M plans, and answering questions. (Note: trainers and technical assistance providers would need to be carefully selected —they must be willing to help new people get started in the field; sometimes this would mean hiring experts from other regions since experts from the local region may be reluctant to train future competitors.)

Maintenance Staff Training and Certification

Building maintenance staff can perform some commissioning work, and they are very important for maintaining commissioning savings. The Northwest Energy Efficiency Council operates a building operator training and certification program with two levels of proficiency. People trained at the highest level are qualified to maintain the high level of building operation that commissioning initiates. The program includes certification in order to help building owners identify skilled staff and to help skilled staff get recognition and possible promotions for gaining these skills (Putnam 2000). The same program is operated in the Northeast by Northeast Energy Efficiency Partnerships. Other operator certification programs are run by BOMA (BOMA 2000) and the Association of Facility Engineers (AFE 2000). Each program operates in a different way, appeals to a different niche among operators, and works with the networks for operators that exist in different regions. Such programs should be available in each region with a retrocommissioning program, and designed to reach operators with a wide range of skills and knowledge.

Financial Incentives

Financial incentives would make it much easier to market commissioning services and substantially increase the number of projects that could be undertaken in the initial years of the program. Based on experience in the Northwest and California, we recommend that incentives cover at least 50% of the cost of commissioning services. On the other hand, the building owner should also pay a portion of the commissioning costs so that they have "buy-in" on the project. In addition, incentives for the implementation of capital measures identified during the commissioning process could increase savings significantly (by *capital measure* we mean measures that have a significant cost to the building owner and that are not paid back with savings in the first year). These incentives, for example, could pay half the cost of capital measures or could be sufficient to buy-down the cost of these capital measures to a particular simple payback period (e.g., 12 months). Dodds, Baxter & Nadel (2000) provided information on incentives offered by many commissioning programs operating in 2000 .

In addition to these core program activities, there are several additional activities that could improve the effectiveness of the program, including additional market research, tenant education and marketing, and cooperation with other retrocommissioning programs on procedure and tool development. These additional activities are discussed in the sections below.

Additional Market Research

Some market research on building O&M and commissioning practices has been conducted. For example, reports with market research components include a manual sponsored by DOE on commissioning existing buildings (Haasl and Sharp1999), a study for the Northwest Energy Efficiency Alliance on commissioning practices and needs in the Northwest (SBW 1998), and a research project on O&M practices commissioned by a group of utilities in the Northeast (RLW Analytics 1999). What is still needed is more focused research in other regions to determine current baseline commissioning knowledge and practices, and reactions to various strategies to increase local use of commissioning. Also, there is a need for further market research to explore specific markets for specific approaches, such as focus groups or interviews with engineering firms and specific types of customers to explore their interest in different business and training models for optimization services.

Tenant Education and Marketing

For leased space with “triple net” leases (where tax, insurance, and operating costs — including energy costs — are passed onto tenants), in order to help motivate owners to improve building operations, it would be useful to educate tenants about the range of triple net payments in their local area, and to encourage prospective tenants to consider the sum of rent plus triple net costs when they compare buildings. An example of such a marketing program is the Better Bricks program recently started by the Northwest Energy Efficiency Alliance (NEEA 2000). Simple ways to help tenants identify efficient buildings, such as the new ENERGY STAR Buildings™ program, would also be useful. Creative approaches in which tenants and owners share commissioning costs and benefits should also be explored.

Procedure and Tool Development

Procedures for commissioning existing buildings are still in their infancy. Peter Herzog, a consulting engineer, has developed some procedures and written a book outlining how to develop an in-house team to commission specific end-use processes (Herzog 1997). Many organizations and firms have drafted procedures including Portland Energy Conservation, Inc. for DOE and Texas A&M University.

There are a wide variety of services offered by different service providers, ranging from simple low-lost O&M services to extensive metering, data analysis, and trouble shooting. There is also substantial variation in the systems covered, with some providers focusing on one or several pieces of equipment (e.g., chillers) and others focusing on the whole building. While different service packages may be appropriate for different customers, when all packages are labeled "retrocommissioning" it makes it difficult for potential customers to understand what services they are offered and it also makes it difficult for providers to market their services relative to other providers that are offering differing services. There is a need to better define specific retrocommissioning packages (e.g., "full commissioning," "commissioning-lite," "chiller commissioning," etc.) to match the needs of different customers and the skills of different providers. For each of these service packages, standard tools and procedures could assist new providers in getting started in the field and could also assist current providers in streamlining their operations. Procedures should be flexible enough to service different building types, scales, systems, and design intent.

Local commissioning programs around the country should work together on the development of common definitions and additional procedures and tools that would make training, marketing, and service delivery easier. Development of a library of public domain procedures, with some index to their appropriate application, would be a useful starting point for new providers and would also be very useful for use in government buildings where there is frequently a need for the establishment of formal procedures. Similarly, improved software and hardware should be developed for better diagnosing buildings. In particular, ways to better build diagnostic capabilities into key building equipment (such as energy management systems, chillers, and economizers) should be explored. With such capabilities, it would be easier to monitor and diagnose equipment operations.

Key Indicators of Success

Given the goals of this program, which are to both reduce peak demand and to overcome barriers so that recommissioning and good building O&M grow in the marketplace, indicators of program success should include:

- Steady increases in building owner and manager familiarity and interest in commissioning and good O&M procedures;
- Growth in the number of skilled local commissioning service providers;
- Steady growth in the number of commissioning projects undertaken;
- Good average energy and energy-cost savings (evaluated on a percentage basis so that the depth of commissioning savings can be assessed);
- Proportion of commissioning recipients who implement good operations and maintenance programs;
- Peak energy savings achieved; and

- Good benefit-cost ratios from the customer and societal perspectives.

Cost and Savings Assumptions

Savings

A 1997 review of field data on 44 commissioning projects for existing buildings found that commissioning existing buildings "often result[s] in whole-building energy savings of 5–15% and paybacks of two years or less." Energy cost savings in these projects ranged from 2–49% with a median of 19% (Gregerson 1997). However, given that this program would be a mass production program that works with many different service providers, we would expect average energy savings to be more modest — on the order of 10%.

Little data are available on the peak demand savings of commissioning. However, two programs did collect data on average peak (kW) and energy (kWh) savings, allowing a ratio of energy to peak savings to be calculated. For the Commonwealth Edison program in Chicago, this ratio was 1,950 kWh/kW. For work by Texas A&M on their campus, this ratio was 860 kWh/kW (Dodds, Baxter, & Nadel 2000). In our opinion, the Texas A&M figure is unlikely to be sustained across many projects and the Commonwealth Edison experience is more likely. Based on this thinking, kW savings can be approximated by first estimating kWh savings (based on the 10% estimate discussed above) and then dividing by 1,950.

Cost

The 1997 study on 44 retrocommissioning projects included costs per square foot for all of the projects. Costs ranged from $0.03–0.43 per square foot of building floor area, with a median of $0.17 (Gregerson 1997). More recently, a review of experience with eight retrocommissioning programs found that costs varied from $0.16–0.63 per square foot, with an average of $0.34. However, these latter programs were a bimodal distribution, with four of the programs ranging from $0.16–0.19 per square foot and the other three ranging from 0.52–0.63. These latter programs either used out-of-state service providers or involved very extensive continuous commissioning services. Based on these data points and considerations, we would estimate that commissioning, on average, should cost approximately $0.20 per square foot. All of these figures include costs to implement low-cost commissioning recommendations.

Non-Energy Costs and Benefits

In addition to direct energy savings, there are numerous citations in the literature on how specific commissioning projects have improved occupant comfort (e.g., by eliminating hot and cold spots) and improved equipment reliability and extended equipment life (e.g., because equipment cycles on and off less often). No systematic study has been conducted on how extensive these benefits are on average.

Measure Life

To our knowledge, there are no studies on the lifetime of commissioning energy savings. In practice, the lifetime of savings would vary from project to project, and could range from just a few months (for projects that are not maintained and where building use changes) to in perpetuity (for projects that are very well maintained. A 1998 analysis for the Northwest Energy Efficiency Alliance estimated an average measure life of 7 years (Suozzo et al. 1998).

Possible Market Penetration Rates

As of this writing, commissioning programs are only in the pilot stage. A typical trajectory for commissioning programs might be 4-12 projects in the first year (Dodds, Baxter, & Nadel 2000). However, in New York State, a pilot chiller retrocommissioning program signed up more than 130 participants in just a few months (Henderson 2000). Based on these different experiences, we estimate that a good full-scale program could maybe complete a dozen projects in the first year, perhaps 40 in the second, and on the order of 100 per year thereafter until about 50% of the target market is served. Thereafter, participation rates would slow as the program seeks to serve harder-to-reach customers.

5. Commercial and Industrial Lighting Retrofit Acceleration Program

Overview

The purpose of this program is to increase the saturation of efficient lighting among existing commercial and industrial buildings. The program accelerates and broadens the efforts already underway by customers and a wide array of contractors to replace obsolete lighting systems with the more efficient systems that have become common practice for most new construction. For the proportion of the building stock that replaces lighting periodically to upgrade appearance (i.e., replaces fixtures sometimes during remodeling), a large proportion of the savings from this program would occur with or without the program over the next 15–20 years. Nevertheless, accelerating the large amount of available low-cost savings would produce significant benefits in areas where there is a need for near-term, large-volume savings. This program would be complemented by a separate but related effort to enhance the quality and efficiency of common practice for lighting design, as described below.

The retrofit acceleration program follows the model of highly successful programs that have evolved over more than a decade and are relatively easy to implement. Programs at National Grid and Conectiv Power Delivery were selected as models for various components because the programs are well-known to the authors, the programs have established track records, and further information is readily downloadable on the Web. Key features are described below.

- Customers would be provided with a range of technical assistance suitable to the scope of each project.
- Prescriptive and customized (site-specific) rebates would be provided.
- Higher rebate levels and an optional separate procurement process are proposed to address the particularly hard -to-reach small business customers (<100 KW). The small business component would provides the minority of the savings and could require higher expenditures per kWh, but would likely have the greatest impacts after 5 years. This is because smaller businesses are less prone to adopt new technology on their own.
- The program would be promoted directly by the utility or other program sponsor, but also would be designed to complement the efforts of energy service companies and other proactive marketers of efficiency.

Target Market

The target market is all existing buildings that do not yet have high-efficiency lighting throughout the structure. While this encompasses a wide range of customers, the following groups are prominent:

- Hundreds of thousands of small-scale businesses with modest individual electric bills but huge cumulative potential savings.

- Larger buildings, including many retail buildings, that are leased on a short-term basis and where the tenant pays electric bills. In these situations, the owner has no responsibility for the bills and tenants have no long term interest in capital investments in the buildings, so many owners have been slow to adopt efficient lighting.

- Large institutions and firms with limited capital or internal organizational knowledge, or internal barriers to energy efficiency decision-making and contracting. In particular, many federal and state buildings have not yet been retrofit. In areas where there have not been extensive prior programs, many local government buildings also use obsolete, inefficient lighting. While energy service companies in some of these areas have addressed large institutions, many smaller ones remain largely untouched.

- Many buildings retrofit in the early 1990s with efficient magnetic ballasts and 34 W lamps could experience much higher savings with more aggressive approaches.

- New technologies that are easily retrofit, such as pulse start metal halide lamps for high intensity discharge (HID) applications, create additional opportunities even for buildings that have previously installed efficient hardware.

- In recent years, utilities have informed the authors that even sophisticated high-tech companies are still installing T-12 lamps and electronic ballasts in large new buildings simply because they are paying attention to other issues. The lesson is that retrofit opportunities can be found virtually anywhere.

For purposes of incentives and delivery structure, the market is divided into businesses with loads over 100 kW (including chain stores of smaller buildings) and businesses with loads under 100 kW.

Efficiency Measures

The program includes *any* retrofit lighting efficiency measure that clearly reduces peak load. However, to simplify and accelerate contractor participation, it would useful to pre-calculate typical cost and savings, and establish prescriptive incentives for more common measures. For example, National Grid (formerly New England Electric) offers incentives separately for each of the following types of equipment:

- T-8 lamps and electronic ballasts (incentives only available for retrofits);
- A variety of different flourescent fixtures that are highly reflective and use efficient lamps and ballasts —fixtures are differentiated to reflect different costs and efficiencies;
- Compact fluorescent lamps with hard-wired ballasts (screw-in compacts are less permanent and often pay back so quickly that an incentive is not needed);
- Light-emitting diode (LED) exit signs;
- LED red traffic lights (Note: some other program sponsors also provide incentives for green LEDs.);
- Pulse start metal halide retrofit kits;
- New pulse start metal halide fixtures;
- New high pressure sodium fixtures;[18]
- Wall-mounted and remote-mounted occupancy sensors;
- Daylight dimming systems;
- Occupancy-controlled high-low control systems — for fluorescent and HID lighting; and
- Fluorescent de-lamping with reflectors.

Specific prescriptive measures, incentives, minimum performance requirements, and other features are detailed on National Grid's Web site in an Adobe Acrobat downloadable file (National Grid 2000b). In addition, as discussed below, other lighting improvements are eligible for custom incentives.

National Grid's basic approach to prescriptive lighting rebates is to specify minimum watt reductions per fixture and specify quality elements of the installation (such as power factor, total harmonic distortion, and component quality issues such as fixture efficiency). These specifications leave manufacturers and contractors with leeway to design and select a range of products, but avoid situations where shoddy equipment is installed. They also assure that National Grid is paying only for measures that are more efficient than baseline equipment.

National Grid offers an incentive for T-8 lamps and electronic ballasts as one-for-one replacements for T-12 lamps and standard magnetic ballasts. They will also retrofit low-power ballasts (where lighting levels allow) in place of efficient magnetic ballasts (Keena 2000). While these measures reduce load, it is often possible to save much more by reducing the number of lamps and ballasts through use of reflectors or new fixtures. One-for-one swapouts can "lock in" an inefficient fixture layout and thus create lost opportunities for these additional savings. Therefore, it is important, in working with

[18] National Grid does not pay for HPS retrofit kits.

customers and contractors, to encourage the more comprehensive approach wherever feasible. At the same time, it's important to recognize that delamping will not produce adequate light levels in all situations and many customers are not willing to move fixtures.

National Grid complements its prescriptive rebates with a *custom approach*. This is for retrofit measures that do not easily fit into rebate categories. National Grid has a separate worksheet to handle these custom measures. This worksheet also can be viewed as a downloadable Adobe Acrobat file (National Grid 2000b). Among the many strategies eligible for this approach are use of T-5 lamps to replace HID lighting in high-bay industrial settings. Because this involves careful fixture selection to assure proper light distribution, and because there are other alternatives that may be preferable in some situations, National Grid addresses this as a custom measure instead of providing a prescriptive rebate.

Program Strategies

The market infrastructure to retrofit buildings with efficient hardware is in place.[19] The equipment is available in volume and with predictable quality; numerous contractors market, finance, and manage this type of retrofit; customers have seen the equipment; and so on. In fact, this year a consensus was reached between efficiency advocates and lighting equipment manufacturers to recommend equipment standards that would essentially outlaw magnetic fluorescent ballasts for new fixtures by the middle of this decade, and outlaw magnetic ballasts for most replacement applications in 2010. In September 2000, DOE formally adopted these consensus recommendations (Federal Register 2000). However, ballasts and lamps can last for many years, so acceleration of this trend would produce significant savings. Furthermore, many technologies that could be retrofit are not covered by this standard.

Customers who have not yet converted their lighting systems often have a number of firm-specific issues that make it difficult for them to address efficiency. These issues were discussed to some degree in the section on the target market, but are summarized in Table C-15.

The barriers are many, and no single approach could address all these barriers. However, private contractors are achieving some retrofit savings with the most motivated customers. Program sponsors have been able to add significant savings (more savings per building and more customers) by offering programs with incentives; multi-pronged marketing; and streamlined, intensive technical assistance. These tools help by calling attention, reducing paybacks, increasing credibility, taking some of the management burden off the customer, and simply forcing a decision.

[19] Except for cutting-edge technologies such as T-5 lamps and daylighting where only some designers are proficient.

Table C-15. Market Barriers to Commercial and Industrial Lighting Retrofit

Market Barrier	Key Issues
Customer Access to Information	• Many customers do not have the technical familiarity to manage contracts to install efficient lighting or to do the retrofits on their own. • Customers often lack expertise and time to engage in performance contracts. • Early performance problems with reflectors, electronic ballasts, and motion sensors have left some customers gun-shy; they do not know that consistency has improved and don't know how to specify highest-quality products. • Customers usually are less familiar with more recent products such as pulse start metal halide lamps. • Many customers do not know how much light they need, so they are conservative about reducing lighting levels. They also don't know that quality reflectors and fixtures could improve light distribution.
Customer Organizational Barriers	• Customers often lack the time and confidence to perform quality assurance. • Many customer organizations (small and large) have not assigned responsibility to any individual to carry out efficiency measures. This hampers decisions and limits expertise. • In many large organizations such as state and federal government and multi-site corporations, the unit that pays for construction often is not the unit that pays energy bills, and the two do not communicate effectively about management of costs. • Many businesses and government entities consider energy efficiency and lighting improvements to be a low priority for funding because energy costs are a small part of their overall operating costs.
Financial Barriers	• Many government entities have legal or political barriers to borrowing (although leasing is possible in many cases). • Split incentives — properties on short-term leases often leave the owner with no responsibility for electric costs and the tenant with no long-term interest in the property. • Small businesses are often run on a cash-flow basis and lack capital for even quick payback investments.
Scale Issues	• Many hundreds of thousands of customers are too small to attract the attention of contractors or engineering firms. • Performance contractors (that provide off-balance-sheet financing as part of its service) typically target transactions of at least a hundred thousand dollars, and most contractors target larger transactions than this. These criteria exclude all but the largest commercial and industrial customers from performance contracting.

Marketing

The program should be marketed extensively to customers and trade allies. National Grid, for example, works directly with larger customers, but has also set up contracts with a group of trade allies to augment staff in marketing the program to medium-sized customers. Trade ally training sessions for other contractors are also held. Special arrangements have been made to encourage energy service companies to participate in both technical studies and measure installation. In an effort to keep prices down, National Grid has also set up the "Buyers' Alliance," a form of a buyers' club. National Grid competitively selects specific firms (one per equipment type) to offer low prices on specific equipment types. National Grid then offers (at no profit to itself) the customer the option of using the Buyers' Alliance contractor to supply equipment or working with a contractor of the customer's choice to procure equipment. While the program would be workable without this arrangement, it helps assure a competitive price on smaller equipment installations.

Financial Incentives

National Grid's incentives are detailed on its Web site (National Grid 2000a, 2000b). In general, National Grid pays about 40–50% of the cost of prescriptive efficiency measures. Prescriptive incentive levels for specific items are fine-tuned based on market response through an annual review process. The *custom* incentive is set at 50% of equipment cost.

These incentive levels would be sufficient to create large-scale program demand. Areas where less efficiency has already been implemented (ergo there is more pent-up demand) could use lower incentives for a time. However, with significantly lower incentives, there would be the danger that a large proportion of the transactions that would be subsidized through the program would occur without the program. Higher payments would accelerate demand for the program, resulting in a smaller share of "freeriders."

National Grid's custom incentives are paid as a percent of equipment cost. They have chosen to pay a share of cost because the cost/kW or kWh from different measures varies dramatically. Costs used to calculate incentives are based on bids or invoices that are reviewed for reasonableness. Savings for custom measures are determined through a technical study, usually performed by a utility contractor but sometimes provided by an equipment vendor.

Other utilities have chosen to pay a fixed $/kW for custom incentives, or a fixed amount per fixture, to reduce "gaming" of costs by the contractor and to simplify technical review.

Financing

National Grid also helps customers locate financing for their share of the cost of efficiency measures, working with a variety of banks and other lending and leasing firms. These offers complement financing available through many contractors and through the customers' own contacts. National Grid facilitation for financing has proven to be valuable, but is used only in a small minority of transactions. Additionally, National Grid offers customers with loads less than 100 kW the option of financing their share of costs on the utility bill, through National Grid's small C&I program. Other utilities have offered this option and it has proven to be an important complementary lever to increase participation.

Quality Control

The key quality control steps would be review of the proposal and site inspection. Proposal review for prescriptive measures would verify that the specified equipment would save the indicated number of watts compared to prior equipment, would meet program requirements, and would be appropriate for the customer use of the space. Inspections would confirm that the specified equipment was installed properly. Payment would be made after installation. When a contractor would begin work in a program, it would be prudent to inspect all sites. Where contractors have installed equipment in many buildings and have established performance records, post-installations could be on a sample basis.

Small Building Approach

Smaller businesses (e.g., under 100 kW at all sites) present a special problem. Smaller transactions tend to have higher analysis costs, and due to the lower volume, higher equipment costs. Small business owners have less time to deal with efficiency or with contractors, and the savings/building tend to be smaller. As a consequence, small businesses tend not to respond in large numbers to the type of program described above.

The simplest way to address this problem would be to simply increase incentive levels for smaller business. This would hypothetically encourage contractors to develop special services to bring in smaller customers. However, the use of turnkey contractors has met with limited success at utilities such as Sacramento Municipal Utility District and United Illuminating. Both these utilities decided to increase the degree of utility administration (while still using contractors for audits and installation) to reduce costs and increase program effectiveness.

National Grid addresses small businesses with a special program approach involving bulk purchase of both labor and equipment and direct installation by utility contractors. Its small C&I program is one of the most successful in the country, having treated two to four thousand customers per year for nearly a decade. They have reached about a third of their small customer base. Under National Grid's approach, a handful of firms are competitively selected to provide checklist audits (using an utility-determined standardized format) and install most equipment. Equipment suppliers are selected through a separate competition to provide large volumes of specific types of common measures. The installation contractors use a utility computer system to order the equipment and have it drop shipped to the site for installation. A separate specialist contractor installs case cooler efficiency measures.

National Grid's share of the cost was originally 100%, but over several years has been lowered to 70–80% (varies by state). This has significantly increased the number of customers that refuse to participate, but the program is still able to address thousands of customers per year. To help induce participation, the utility offers to finance the customers' share of costs on the utility bill.

For *custom* installations, there would be one major difference — a more detailed proposal review to verify the reasonableness of the engineering assumptions behind the savings estimate and the adequacy of the lighting levels. The cost estimate, which drives the custom incentive, would also be reviewed for reasonableness.

Relationship of Program Strategies to Market Barriers

Table C-16 shows how these program strategies would address each of the key market barriers to efficiency investments in the C&I lighting retrofit market.

Table C-16. Market Barriers and Intervention Strategies for Commercial and Industrial Lighting Retrofit

Market Barrier	Intervention Strategy
Customer Access to Information	• Utility staff and contractor technical assistance • Marketing through contractors • Marketing and technical materials • Technical studies where needed
Customer Organizational Barriers	• Utility/sponsor endorsement sometimes focuses attention • Financial rebate opportunity could focus attention • Utility/sponsor assistance in project implementation • Utility/sponsor quality control and administrative advice to customer
Financial Barriers	• Incentives • Financing facilitation • Alliances with performance contractors and leasing firms to overcome government entity restrictions on financing • Financing to produce positive cash flow, preferably on the electric bill
Scale Issues	• Higher incentives for small customers • Bulk purchase/direct install approach to minimize hassle for small customers

Key Indicators of Success

The primary indicator of success for retrofit lighting programs would be the level of savings and participation. It is important to consider the savings beyond what the private sector would accomplish in the absence of utility programs. While this can never be precisely determined, post-installation interviews with customers often reveal their prior intentions.

A secondary indicator would the comprehensiveness with which buildings would be treated. As previously discussed, delamping with reflectors or fixture change-outs can often save much more than one-for-one lamp and ballast swap-outs. Many of the lighting design approaches discussed in the section on the lighting quality enhancement program could be applied to retrofit situations if the customer and contractor are sufficiently motivated and sophisticated.

Cost and Savings Assumptions

Savings

Precise data on the percent of building peak load that has been saved through this type of program are difficult to obtain, in part because many programs have been evaluated as part of larger integrated programs including other end-uses (because many evaluations focus on energy more than peak) and in part because evaluations tend to focus more on total savings than percent of load saved. However, savings from small C&I retrofit programs are often on the order of 10% of total building (for all electricity uses) energy and peak load. In 1999, Massachusetts Electric's (National Grid's largest subsidiary at that time) small C&I program saved an average of 2.2 kW/customer from lighting measures, and an additional 0.2 kW from other measures (National Grid 2000c).

For larger buildings, the savings from lighting ranges from 10–20% of lighting load, and in many cases even higher, depending on the breadth and depth of the retrofit. EPA's program has commonly found it possible to reduce lighting loads by 30–50% (EPA 1999). In 1999, Massachusetts Electric's Energy Initiative retrofit program saved an average of 4.7 kW/participant with lighting measures.

While evaluation issues are beyond the scope of this report, it is important to recognize that lighting-connected load reductions do not precisely match nameplate ratings (Gordon, Quaid, & Gardner 1995). For example, lamp/ballast interactions must be considered, which will sometime increase and sometimes decrease consumption relative to nameplate ratings. Similarly, not all lights are on (therefore saving energy) during peak periods. For example, New England Electric's (now National Grid) study of lighting measures in new buildings using lighting loggers estimated diversity factors in the range of 77–80% during peak hours (New England Electric 1994). Also, the most common technique for estimating lighting energy savings is to multiply lighting load reductions (in watts) times annual operating hours. Several utilities have conducted studies in which they install meters or light-sensing loggers of some type in a sample of buildings. A recent review of nine of these studies, covering on-site measurements at 367 sites, found average annual operating hours of 4005 (Miller 2000).

In addition, since lighting energy savings reduces the heat produced by lighting systems, savings estimates should include reduced air conditioning load due to less heat produced by lights, and the corresponding increase in heating load for facilities with electric heat. Cooling benefits will be higher and heating benefits lower in warmer climates, and the reverse holds for cooler climates. The particular effects vary by region and building type. A recent set of analyses by Lawrence Berkeley National Laboratory examine these impacts in detail (DOE 2000c provides the most recent estimates by building type at the national level; Sezgen and Huang 1994 provide regional data but their numbers are subject to some shortcomings noted in the 2000 report).

Finally, there is the issue of freeriders, meaning customers who participate in a program but would have installed efficiency measures anyway. Some of the most recent estimates of freerider levels for lighting upgrades are provided by a National Grid 1999 survey of participants in its programs. For lighting retrofit measures, National Grid found that freeriders were 0–2.5% of its small customers and

3–5% of its large customers. The low end of the range signifies participants who are clearly freeriders; the high end of the range includes "partial freeriders," which are customers who claim they would have made the improvements eventually but not necessarily soon (National Grid 2000c). Also, as the new DOE ballast standards kick-in after 2005, these long-term partial freerider levels will increase (i.e., incentives provided in 2001–2004 will merely accelerate adoption of electronic ballasts that would have been sold in the post-2005 period.

Cost

In 1999, Massachusetts Electric's large C&I retrofit program, Energy Initiative, provided the following savings:

	Prescriptive Lighting	Custom Lighting*	Combined
Peak MW	4.1	0.4	4.5
MW years	78	6	84
Annual GWh	16	3	19
Lifetime GWh	306	44	350

*Includes lighting controls.

National Grid does not report cost-effectiveness by end-use. However, the overall cost of program implementation, including non-lighting measures, was $1,013/kW and $65/kW-year (undiscounted — i.e., annual kW x measure life), and 1.3 cents/lifetime kWh (cost/lifetime kWh). The lighting measures were among the more peak-intensive and less expensive, so we can only assume that they cost less per kW (National Grid 2000c).

Lighting savings from Massachusetts Electric's small C&I program in 1999 can be summarized as follows:

	Prescriptive Lighting
Peak MW	2.7
MW years	39
Annual GWh	6
Lifetime GWh	83

The overall cost was $1,134/kW, $78/kW-year, and 3.5 cents/kWh. These figures include non-lighting measures, which are more expensive, and so are probably slightly high. However, this program, and its costs, are dominated by lighting measures. Much of the higher cost/kW (compared to Energy Initiative's program) is due to higher marketing and installation costs due to the small savings at each site. This is balanced by the fact that small buildings tend to have fewer freeriders because customers less frequently upgrade efficiency on their own (National Grid 2000c).

A review of the largest lighting programs in the country found that the majority of programs had total costs below 4.4 cents/kWh saved and utility costs below 3.1 cents/kWh. Four programs had costs of about 2.0 cents/kWh saved or less (Eto, Kito, & Sonnenblick 1995).

Non-Energy Benefits

The program would also replace many lighting fixtures that were providing inadequate light and in some cases reaching the end of their useful life. Quality of lighting could be increased or decreased depending on the quality control regime employed by the program sponsor and the quality of lighting contractors and equipment employed.

Measure Life

Controls aside, the life of most lighting measures depends on the time that the fixtures remain in place. The most thorough study of which we know estimated life for a large sample of in-service fixtures. Even in an area with high building growth, the average life was 21 years (Skumatz 1994).

Control measures may have different lives depending on the durability of the sensors and equipment. National Grid estimates a 10-year average measure life for occupancy sensors.

For ballasts installed without new fixtures, life is best measured in hours of use since annual hours vary significantly from building to building. Generally, the equipment rating for specific equipment is useful. One study found a typical life of 70,000 hours (Gordon et. al 1988).

Market Penetration

This would depend on what has already been done locally. High-volume programs have addressed as much as 5% f the total market per year for a number of years. A few very high-incentive programs may have moved faster for individual years (Edgar, Kushler, &Shultz 1998), particularly those operated by smaller utilities that intensively cultivated community involvement (Holt, Gordon, & Tumidaj 1995).

6. Commercial and Industrial Lighting Design Enhancement Program

Overview

The purpose of this program is to capture savings by using equipment and design practices that are more efficient than standard practice in commercial and industrial new buildings, renovations, and remodels. Lighting loads are the key determinant of commercial building peak. Design enhancements beyond current practice could radically reduce peak lighting load in some facilities if both efficient lighting technologies and daylight harvesting were employed. Simple approaches could save an additional 10%. In the best cases, the majority of lighting load would be eliminated.

The lighting design enhancement program would support and be enhanced by efforts to achieve state-level adoption and enforcement of the lighting standards in the new ASHRAE 90.1-1999 standard. It would also encourage efficiency beyond that standard. In states where the ASHRAE code has not yet been adopted, an effective program could increase the odds of acceptance. In states where the code has been adopted, the program could enhance compliance and assure that compliance results in quality lighting systems. In these states, the program could also lay the groundwork for possible future code upgrades.

The program design capitalizes on efforts of pioneering utilities and regional efficiency organizations to develop specific tools to work with the design community. The central structure of the program is a series of custom and prescriptive incentives, supported by a program of technical assistance. The proposed rebates are similar to those in the retrofit acceleration program described above except that:

1. They are keyed to improvements beyond current practice and codes;
2. The custom rebate takes a larger role; and
3. Rebate levels are based on a portion of the incremental cost to exceed current practice and codes, whereas the retrofit acceleration program bases rebates on a portion of full cost.

A special track is recommended for smaller and contractor-designed buildings. In these buildings, lighting design tends to be simple and standardized. Contractors rarely analyze lighting system energy use or light output. For these buildings, the program proposes lighting design guidelines that would be used both to train contractors and to build demand for better lighting among owners, managers, and renters. The guidelines would also create a template for distributors, manufacturers, and other "contractor helpers" to specify efficient, high-quality layouts. Marketing for the guidelines should be targeted at contractors and designers through their associations and through alliances with manufacturers. Training should be held on the guidelines. A series of demonstrations, funded in part through the incentives discussed above, should be individually evaluated, documented, and published, and used as a tool to help build acceptance of the guidelines.

Target Market

This program is targeted at new construction, renovation, and "hard remodels," which involve changing lighting layouts or fixtures.

The "custom design" track is targeted at large buildings where lighting systems are custom-designed. Key targets would include architects, engineers, and lighting designers, including both consultant designers and design professionals working within property development/management organizations. In-house professionals often exist within chains and owner/manager firms specializing in office and retail rental space. Early adopters have often included high-profile office and institutional spaces.

The "small and simple building design" track focuses on buildings where designs are typically copied from site to site with little or no analysis. These include many industrial spaces, smaller and rental office and retail space, and schools. Schools are something of an anomaly in that they are often designed with the help of an architect, but lighting designs are seldom changed from site to site. Thus, the architects who specialize in this work may pay little attention to the lighting system, and may be responsive to comparative tools and approach as the contractors who do not employ a design professional.

Efficiency Measures

A variety of design approaches should be employed, including:

- Elimination of over-lighting and more efficient provision of lighting through fewer, higher-quality fixtures,[20] fewer lamps, designing lighting to focus on areas of use, and better specification of ballast factor.

- More appropriate lighting fixtures for coves and coffers.

- Alternative approaches for accent lighting.

- Additional applications of compact fluorescent lamps beyond those that are commonplace today.
- Use of compact fluorescent lamps with electronic ballasts instead of magnetic ballasts.

[20] These could include T-5, T-8, IR halogen, and many other types of lamps, within fixtures designed to take advantage of the optical properties of each lamp.

- More and better use of dimmers, especially daylight-modulated dimmers, occupancy sensors, and timers.

- Task lighting and indirect lighting to reduce required room lighting levels.

- Individual occupant controls over lighting (through addressable fixtures) — a promising new innovation that may significantly reduce energy and peak use.

- Consideration of specialized controls in peak-constrained areas in order to reduce ambient lighting during extreme peak periods. Such controls may prove to be extremely profitable for owners.

- For smaller buildings, especially for remodels, incentives may still be justified for T-8 lamps and electronic ballasts. Current practices vary locally, but these markets appear to be among the last to adopt these technologies.

Many of these measures involve higher-quality fixtures, more diverse fixtures, and more controls than are commonly being used today. The payoff would be a more aesthetically pleasing and functional space as well as lower energy use.

Program Strategies

Design enhancement is new to many program sponsors, but others have been working with the design community for many years. Some sponsors are concerned that they should not "second guess" designers, essentially taking over the task and liability for adequacy of lighting design. Leading utilities have successfully developed design assistance and incentives that empowers designers by providing them with more information, tools, time to design, and the ability to present efficient options to their clients with modest added cost and clear user benefits.

For lighting design improvements, market barriers are summarized in Table C-17.

Table C-17. Market Barriers to Commercial and Industrial Lighting Efficiency through Design Enhancement

Market Barrier	Key Issues
Customer Access to Information	• Most customers are unfamiliar with design approaches to lighting quality and efficiency. • Customers often do not know how much light they need, so they are conservative about reducing lighting levels. They also often do not know that quality reflectors and fixtures could improve light distribution. • Customers sometimes are not familiar with the connection between lighting quality and occupant performance issues such as worker output, retail sales, and student performance. • Many customers do not have unbiased sources of information and lack the time and confidence to perform quality assurance on lighting design. It is particularly difficult for them to know which designers have expertise in designing to specific levels of quality for specific types of applications.
Customer Internal Issues	• In construction projects, lighting is considered a detail. It needs to "work" and then key personnel need to attend to other things. • Many customer organizations (small and large) have not assigned responsibility to an individual to carry out efficiency measures. This hampers decisions and limits expertise.
Product Definition	• "Quality lighting design" is not well-defined for designers, and especially for users. It involves extensive aesthetics and judgement. This makes it harder for customers to identify, desire, purchase, and verify quality designs.
Trade Ally Issues	• Contracting processes are diverse, but generally favor lower bids. Unless quality is a requirement in a bid, quality proposals are risky. • Given limited developer interest and budgets, the conservative approach is to "design it like I did last time." • Smaller buildings are not designed — they are often copied from templates or prior designs. The design process often consists of a counter-top or cell phone discussion with the manufacturer's or distributor's representative. • Contractors may be trained to follow more complex strategies and layouts, but the changes must be presented gradually, within the context of their existing practice. • Even for many larger structures, architects and engineers copy the last design that passed muster, adjusting as necessary for codes or special needs. While skills are higher than among small building contractors, the culture is not oriented towards analysis or efficiency. • Many designers regard efficiency as a "design constraint" more than a design value. They do not regard it as a tool for enhancing their value or winning jobs.
Financial Barriers	• In many organizations, financial managers do not regard efficiency as a source of revenue or major savings; their attention is on maximizing revenue as a higher priority than cutting costs. Energy costs are swamped by other factors in purchasing decisions. • Efficiency improvements are often "value engineered" out of construction projects to assure that funds are focussed on more visible problems, critical code issues, etc. • In large organizations such as state and federal governments and multi-site corporations, the corporate unit that pays for construction often is not the unit that pays energy bills, and the two do not communicate effectively about management of costs. • Many developers provide a "build-out allowance" for lighting for tenants, which restricts investment in quality lighting.
Design Methods and	• Some buildings are designed to be as flexible as possible to meet the needs of tenants who may change. Flexibility could lead to generic over-lighting if not carefully thought

Values	through.

While awareness should be the first program barrier addressed, the most crucial barrier will be product definition. Lighting design is not a commodity like a ballast. Lighting design is a package of enhancements to selection, placement, and control of a wider variety of equipment than a lighting contractor normally considers. Good lighting design is more complex to ask for or offer, so it is more difficult to establish a market where the buyer understands what is being sold and can verify its legitimacy. Even efficiency-oriented designers don't always agree on the "best" approach to a space. As a consequence, efficiency and quality would be considerations for a select group of elite designers for elite buildings where the clients are looking for ways to distinguish their building.

Detailed discussions with members of the lighting design community have revealed that energy efficiency will never be a high priority for their work (Gordon, Tumidaj, & Coakley 1995). Thus the primary focus of this lighting design enhancement program is on enhancing the market position of "high quality lighting" as a valued, salable, and verifiable commodity.

There have been significant efforts in recent years to address these barriers, ranging from development and promotion of quality/efficient lighting guidelines for contractors, more complex lighting guidelines for high-end designers, lighting demonstration and training facilities, contractor certification, federal branding programs (ENERGY STAR), etc. At the moment, the profusion and lack of coordination of these effort creates an additional barrier to more interested developers, designers, and owners. The proposed program tries to create a "tree" to incorporate all of these appropriate experiments in a way that is coherent to customers and manageable for program sponsors.

Technical Assistance

For buildings where designers are involved, the program should offer both direct technical assistance and reimbursement to contractors for the extra time involved in efficient equipment analysis and design.

For high-end buildings, technical assistance could be provided using the system currently employed with minor variations in several of the more ambitious utility new construction programs (e.g, National Grid, NSTAR, Northeast Utilities, and Conectiv Power Delivery). These programs offer modest compensation to designers for the added cost of considering efficient equipment, and also offer the services of "efficiency expert" contractors to work with designers.

For example, Conectiv Power Delivery of New Jersey (Conectiv) offers up to $2,000 to compensate for analysis of a lighting system that results in a high-quality design, subject to several conditions to assure that the design exercise is effective and necessary. A contractor working for Conectiv will also assist with advice on lighting system design, including:

- Plan review and analysis of energy efficiency options
- Walk-through audit of current facility
- Consultation on selecting and specifying energy efficiency measures
- Basic design assistance (small new construction and/or remodeling)
- Basic measure/system/project analysis and recommendations
- Assistance with incentive applications and program compliance

Some customers rely more on Conectiv Power Delivery's contractor, and others rely more on their own designer, compensated in part by the utility. Conectiv also offers higher incentives for efficient design work involving multiple end-uses. Details are available at Conectiv's Web site (Conectiv 2000b).

For smaller and simpler buildings, there really isn't much of an existing design process to influence. Contractors typically take designs from prior designs or "templates." or work with suggestions provided by the lighting distributor's or manufacturer's salesperson. There is little or no numerical analysis. The Design Lights Consortium (DLC), a group of utilities and other conservation proponents in the northeastern United States, has developed an initiative to directly address this market. Their KnowHow series of lighting design guidelines (DLC 2000) are the centerpiece of this campaign. These guidelines are intended to help create excitement about quality efficient design among contractors and their clients. The guidelines offer "good, better, and best" approaches to lighting design for ordinary commercial spaces. The "good" level is generally not much more efficient than the recently passed ASHRAE lighting standard but assures reasonable lighting quality while meeting the standard. "Better" and "best" standards incorporate progressively higher-quality and more efficient lighting.

The first three guidelines (small office, small retail, and school) are about a year old and have been used in several training classes and several demonstration projects. Three case studies are available (DLC 2000). They have generated significant excitement among both manufacturers and contractors. They are currently being incorporated into code compliance training in Massachusetts. While contractors seem to be using some of the information from training in the guidelines, the extent of their influence is not yet clear. An evaluation is currently being planned. Also, additional guidelines are being developed for industrial lighting and for skylighting in retail and industrial buildings.

The case studies are used to demonstrate how to apply the guidelines, and the case study process is showing some of the complications of marketing high-quality lighting. Because the focus is on quality, the equipment recommended in the guidelines cost more than simple cheap fixtures that could provide efficiency. However, the guidelines assure that the lighting levels meet user needs, and hopefully can create more of a market demand for better lighting for ordinary buildings.

Based on very early feedback, it could prove useful to have additional informational pieces to make the guidelines attractive for purchase and leasing agents (i.e., a shorter "sell" piece") and to help contractors actually lay out conforming lighting systems (i.e., case studies and manufacturer-provided model layouts). However, the guidelines appear to offer the core for a potentially effective approach to "next wave" lighting for smaller buildings. DLC is actively recruiting manufacturers as allies and encouraging them to develop conforming model layouts.

We recommend that sponsors who wish to promote good lighting in small buildings work with the DLC to access their guidelines and help them evolve. In addition, we recommend that sponsors offer training workshops in use of the guidelines, provide custom incentives (as described below) to help get a number of buildings in the field that conform to the guidelines, and develop local case studies. Additionally, the sponsor's technical assistance staff could help contractors through their first few experiences in designing guideline-conforming buildings.

Marketing

The long-range market strategy for this Lighting Quality Enhancement program is to influence the market so that customers are motivated to purchase high-quality efficient lighting for reasons of appearance and functionality, with reduced demand and energy use as a secondary consideration. However, in the short run, many sales could also be made based on energy savings re-enforced by utility incentives. Neither the "quality" nor the "energy savings" approach would work everywhere.

Critical marketing targets would include:

- Designers (mostly architects, engineers, and professional lighting designers for larger and high-end buildings and schools, mostly contractors with limited technical background for smaller and low-priced buildings)
- Developers
- Purchasing, and rental agents within customer organizations
- Personnel who upgrade buildings for rent within property management firms

A keystone to marketing would be demonstrating that quality lighting helps meet developer objectives, such as faster rentals and sales, higher occupancy, higher rents, more satisfied and productive occupants, higher retail sales volume, etc. A national consortium is working to develop information on productivity benefits of efficient lighting (Light Right Consortium 2000). An influential set of studies demonstrating productivity benefits of quality lighting in retail schools (better grades) and retail buildings (better sales) is available (Heschong, Wright, & Okura 2000; Okura, Heschong and Wright 2000).

A more direct approach to showing non-energy benefits would be to conduct "impressions research." This would amount to encouraging personnel who make purchase and rental decisions to tour buildings that meet quality lighting standards and then through other buildings that are similar except that they do not meet those standards. The impressions of real buyers and rental agents (assuming that they prefer quality lighting) would likely make a very direct impression on their peers.

Communications materials should be crafted for contractors, designers, engineers, developers, rental agents, etc. For designers and contractors, professional associations would provide useful allies and leverage points for communication. However, significant one-on-one in-person communication would be necessary to help designers adapt new approaches.

With respect to the lighting guidelines, DLC has developed a detailed marketing plan for 2000. Training, trade ally alliances, trade shows, and direct contact are among the approaches being applied.

The retrofit acceleration program described above might also provide a marketing avenue. Through the custom retrofit incentives proposed for that program, there would be an opportunity to promote advanced lighting designs. However, it is important that very simple approaches should also be available under that program to meet its primary purpose — capture of high-volume, near-term savings.

Financial Incentives

For both the "custom design" and "small and simple building design" tracks, a number of utilities offer cash incentives to help defray the cost of more efficient lighting equipment in new buildings, renovations, and remodels. These incentives typically pay a portion of the incremental cost of more efficient equipment. Traditionally, these incentive strategies have focussed simply on efficiency, and incentives have been structured to sell adequate lighting quality, not superior quality.

Many of the "next wave" lighting strategies require redesign of fixture layouts. Beyond a point, reduction in lighting intensity is possible only with higher-quality components and new layouts to provide more-available and better-distributed light. In some cases, the components would be affordable only if the customer considers the improved "look" of the space to be an asset that helps justify the cost.

For these reasons, one-for-one equipment incentives, while valuable, would be secondary for this program. The centerpiece of the incentive strategy is custom incentives, which would help pay for any measures that the sponsor deems to be acceptable. Since much of the value would come from intangible improvements to the "look" of the space, typical cost-effectiveness screening would not be useful; while the non-energy benefits have been demonstrated in research studies (as discussed below), they would be too difficult to quantify on a site basis. If these benefits weren't considered, many measures that would be appropriate would be eliminated from programs.

Sponsors would have an option of two strategies toward prescriptive incentives. First, some utilities have tried to push as many measures into prescriptive rebates as possible. This is done for two reasons:

- Minimize the delay and expense of a custom calculation for every site.
- More clearly promote classes of efficient product for different types of common practice fixtures.

National Grid clearly falls into this camp. Its prescriptive rebates are downloadable in Adobe Acrobat from their Web site (National Grid 2000a). Rebates are available for a variety of high-quality fixtures, LED exit lights, and controls. Payments are generally established per unit of equipment. Minimum watts per control unit are specified, as are acceptable power factor and harmonic distortion. Incentives are designed to cover the majority but not all of the incremental cost of hardware alternatives.

Other utilities have chosen to rely more on custom incentives. Prescriptive rebates are used only for customers who are unlikely to utilize the more complex custom format (i.e., small buildings and specific industrial opportunities) or for measures where the watt/kW incentive does not work well (i.e, controls).

This approach keeps the program materials relatively simple for the newcomer, and has less tendency to drive designers toward specific solutions. For a small program sponsor, it is resource-intensive to keep a diverse set of prescriptive incentives current.

Conectiv provides an example of this approach. Their incentives and conditions are available from their Web site (Conectiv 2000a). Prescriptive incentives are provided only for:

- T-8 lamps and electronic ballasts in new buildings under 50 connected kW and remodels of facilities under 100 kW ($10)
- Hardwired compact fluorescent lamps in the same classes of smaller buildings ($2.35–$18.25, depending on the size and type)
- Occupancy sensors ($15/fixture, up to cost of sensor)
- Daylight dimming ($15/fixture up to cost of the sensor and controller)

Based on experience working with Conectiv Power Delivery, we recommend a custom incentive that pays $1/watt for reductions in lighting use below established baselines. The intention would be to pay the majority, but not all, of the costs of efficient equipment. It might not pay as large a share of the costs for the highest-quality equipment, but the goal is to sell that equipment based on lighting quality improvements as well as energy savings.

Either the prescriptive or the custom approach would work. We believe that the National Grid approach is superior for sponsors who would be willing to invest the time and expertise in keeping a diverse set of rebates up-to-date and working with contractors to understand the various rebate options. However, the Conectiv system has worked well for it. The system has required that the implementation contractor perform more site-by-site work, but the contractor has developed streamlined procedures for doing this.

To estimate incremental cost for custom measures and establish lists of rebate measures, it would be necessary to establish a design baseline. For states where design is fairly advanced from an energy standpoint or where the ASHRAE 90.1-1999 standard (or similar) has been implemented, the lighting power densities in that standard could provide a baseline. Where building codes have not been upgraded in many years, or are not thoroughly enforced, the baseline could be somewhere between the old ASHRAE code and the new ASHRAE code. For example, after reviewing recent building designs, Conectiv elected to pay incentives for lighting designs with lighting power densities 30% more efficient than the older ASHRAE 90-1989.

Financing

For new construction, we do not believe that direct utility financing is critical. The sort of financial referral service and close coordination with energy service companies described for the retrofit acceleration program (described above) would sometimes be useful, especially for remodel and renovation projects.

Quality Control

Sponsors should provide quality control similar to that for the retrofit acceleration program. They should also track incremental costs of equipment in the market to assess whether incentives continue to be appropriate or need modification.

For the case studies, sponsors should confirm that designs meet the guidelines. Individual sponsors or DLC should review material from manufacturers or others that portends to conform to the guidelines. As of this writing, the DLC is trying to forge alliances with market actors, which should help in this regard.

Relationship of Program Strategies to Market Barriers

These are summarized in Table C-18.

Table C-18. Market Barriers and Intervention Strategies for Commercial and Industrial Lighting Design Enhancement Program

Market Barrier	Intervention Strategy
Customer Access to Information	• Utility staff and contractor technical assistance • Marketing and educational materials for customers to help them understand the benefits

	• Marketing through contractors • Technical studies where needed
Customer Internal Issues	• Utility/sponsor quality control • Design guidelines for contractor-designed jobs • Prescriptive equipment recommendations • Demonstration of how to build quality specifications into lighting bids and what to expect from contractors
Product Definition	• Establishment of baseline practices • Clear branding (through guidelines) to help customers and developers focus • Training and technical assistance • Design guidelines for contractor-designed jobs • Case studies to show designers that lighting efficiency and quality are compatible
Trade Ally Issues	• Creation of demand for lighting quality so firms want to learn how to provide it • Simplified, guideline-driven approach for smaller buildings; technical assistance for custom jobs • Assistance for smaller contractors in advancing a step at a time.
Financial Barriers	• Incentives for efficient designs • Case studies showing financial benefits, both energy and non-energy. Focus on sales and leasing benefits for developers and property managers. • Direct work with government entities to develop channels for funding efficiency
Design Values	• Case studies of flexible designs that meet needs of rental properties

Key Indicators of Success

The indicators of success for lighting design enhancement programs would include the following:

- Interest in the guidelines among businesses and contractors (an early indicator)
- Increased broad interest in quality design
- Peak and energy savings
- Support by professional groups (another early indicator)
- Attendance at training sessions (a second-stage indicator)
- The square footage of target market that is built/remodeled using lighting guidelines (for the third year and beyond)
- The extent to which contractors and others rely on lighting guidelines (throughout the project)
- The extent of customer satisfaction and demonstrated non-energy benefits from the use of the lighting guidelines in pilot projects (once case studies are in place)
- The extent to which the lighting design community supports and implements incorporating the lighting standards in the new ASHRAE code into local and state codes

In addition to these market indicators, it would be prudent to conduct some evaluation, including use of metered data, for maturing technologies and those where savings would be sensitive to design, installation, and operation (e.g., controls, particularly daylighting).

Cost and Benefits

Savings

Savings would be highly dependent on baseline practices. The previously cited study of baseline lighting practices in New Jersey (Sardinsky 2000) developed rough estimates of potential additional savings by building types as follows:

- Retail: 5–25% (sample of 13)
- Offices: 5–30% (sample of 9)
- Warehouse: 40% (sample of 1)
- Schools: 10–25% (sample of 2)
- Nursing homes: 15–30% (sample of 4)
- Lodging: 10–20% (sample of 1)
- Hospitals: 25–35% (sample of 2)

Significantly, most of these buildings had already incorporated "basic" efficiency measures such as T-8 lamps, electronic ballasts, and compact fluorescent lamps. The variation within building type reflects both building-to-building variation and some uncertainty regarding the estimates. While this analysis addressed energy savings, most of the savings were from measures with proportional energy and peak effects.

Lighting energy savings also produce cooling energy savings, which vary depending on local climate. As discussed above in the discussion on the lighting retrofit acceleration program, these interactions vary by climate and building type and Lawrence Berkeley National Laboratory developed factors to adjust for these interactions by region and building type.

Other Benefits

Customer benefits were introduced under "Marketing," above.

One additional benefit of acceptance of high-quality lighting from a utility perspective is a higher likelihood that lighting market actors would not resist passage or implementation of an advanced lighting code such as one based on the recently passed ASHRAE standard.

From the point of view of contractors, high-quality lighting provides a way to differentiate themselves in the market, and a way to sell higher-priced quality equipment This generally provides higher gross profit. Manufacturers would also benefit by selling high-quality, higher-cost equipment.

Cost

Costs for additional lighting design depend strongly on the approach. The DLC approach (for smaller and simpler buildings) is a market transformation approach, and assumes that the quality of the lighting would help sell higher levels of efficiency. Therefore, the capital cost of conforming to the DLC approach is relatively expensive, but not all the costs are attributable to efficiency. We expect that costs will decrease as standardized approaches evolve for conforming to the guidelines and high-quality equipment costs drop due to volume and competitive pressures. An example is provided by pendant indirect fixtures. One manufacturer decided to create a mid-priced line for these previously "high-end" fixtures. Now several manufacturers offer mid-priced lines at significantly lower cost than those of two years ago (Sardinsky 2000).

For larger, more complex buildings, utilities such as National Grid and Northeast Utilities have been able to pay incentives at a lower cost/kWh than their avoided costs of energy and peak power. Savings and costs for National Grid's Design 2000 program for new construction and equipment replacement are shown below in Table C-19 (National Grid 2000a).

Table C-19. Savings and Costs for National Grid's Design 2000 Program

	Prescriptive Lighting	Custom Lighting*	Combined
Peak MW	1.6	0.2	1.8
MW years	25	3	28
Annual gWh	10	1	11
Lifetime gWh	153	15	168
Cost/kw-year/kW**			$1,605
Cost/lifetime kW**			$96
Cost/lifetime kWh**			$.02

*Includes lighting controls.
**Includes non-lighting measures

Because these figures incorporate more expensive measures from non-lighting end-uses, the costs for lighting are likely dramatically overstated. It is also important to bear in mind that historically, the cost for the new technologies in the program (e.g., electronic ballasts) have come down over time as they became commodities. This is likely to occur for the technologies currently being promoted.

There are also costs to running the training, developing the guidelines, etc. as DLC is doing as of this writing. Those costs have run around $900,000 for the Design Lights Consortium as a whole over the past 2 years. This amount was spread among six retail utilities to begin with (currently nine) and one state conservation entity. The amount includes about $200,000 for demonstrations, which provide savings but are more expensive per kWh than ordinary program activity because they are designed as showcases and are also learning sites for the program (Dagher 2000).

Measure Life

See retrofit acceleration program description above.

Possible Market Penetration Rate

While there are huge variations, lighting fixtures are on average replaced every 21 years (Skumatz 1994). In an area with a 4% growth rate, the potential market would be 41% of the lighting equipment stock in place at the end of the 5th year.[21]

Possible rates for penetration into this target stock are shown in Table C-20. The long-term rate is based on participation rates in five of the most successful commercial new construction programs (Nadel, Pye, & Jordan 1994).

Table C-20. Penetration of Lighting Design Enhancement Program

Year 1	1%*
Year 2	10%
Year 3	20%
Year 4	40%
Year 5	50%

*Largely for developing administrative system and relationships, training, and case studies.

[21] (1.04(fifth power)-1) + (1/21x5)/1.04(fifth power) = 41%.