U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Advanced Energy Retrofit Guide

Practical Ways to Improve Energy Performance

Grocery Stores

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Nomenclature

ADR	asset depreciation range
AERG	Advanced Energy Retrofit Guide
AFUE	annual fuel utilization efficiency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	building automation system
BOC	building operator certification
BOMA	Building Owners and Managers Association
Btu	British thermal unit
C_0	initial investment and related cash flows in Year 0
CBECS	Commercial Buildings Energy Consumption Survey
$C_{depr,eem,t}$	tax deduction for depreciation of measure/package in Year t
$C_{depr,ref,t}$	tax deduction for depreciation of existing equipment in Year t
C_{disp}	disposal cost of existing equipment
CEC	California Energy Commission
$C_{energy,elec,t}$	annual electricity cost savings in Year t
$C_{energy,gas,t}$	annual natural gas cost savings in Year t
CFL	compact fluorescent lamp
cfm	cubic feet per minute
C_{incent}	NPV of financial incentives
C_{inst}	installation cost of measure/package
C_{mv}	additional M&V costs
CO_2	carbon dioxide
C_{om}	additional O&M costs
COP	coefficient of performance
C_{plan}	cost of project planning
C_{pur}	purchase cost of equipment
CRB	DOE Commercial Reference Building
$C_{repl,eem}$	replacement cost for measure/package
$C_{repl,ref}$	replacement cost for reference case

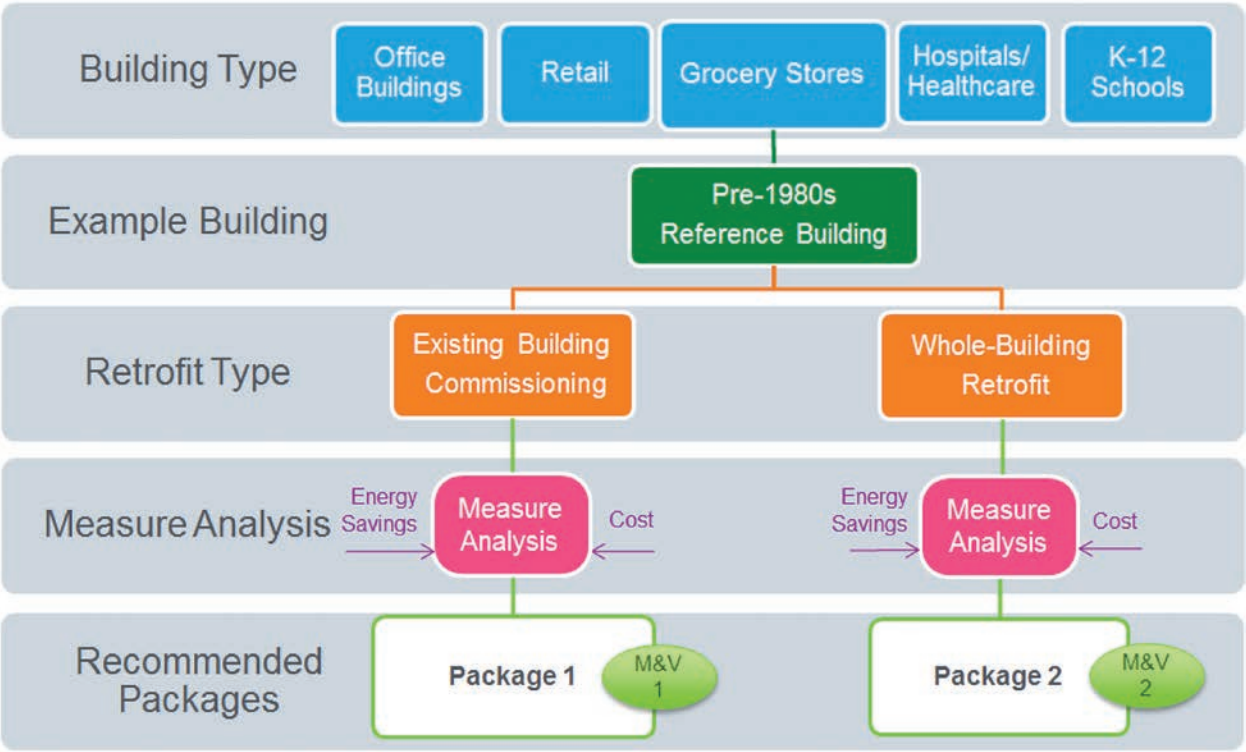
$C_{rem,eem,20}$	remaining value of measure at year 20
$C_{rem,ref,20}$	remaining value of reference equipment at year 20
$C_{salv,ref}$	salvage value of existing equipment
C_t	sum of cash flows in Year t
$C_{tax,0}$	tax benefits associated with disposing of existing equipment
CV	constant volume
DCV	demand control ventilation
DF	real discount factor
DOAS	dedicated outside air system
DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Renewables and Efficiency
DX	direct expansion
EBC_x	existing building commissioning
EEM	energy efficiency measure
EIA	Energy Information Administration
EMS	energy management system
EPA	U.S. Environmental Protection Agency
ERV	energy recovery ventilator
ESCO	energy service company
EUI	energy use intensity
FEMP	Federal Energy Management Program
ft^2	square foot, square feet
ft^3	cubic foot, cubic feet
HVAC	heating, ventilation, and air-conditioning
IAQ	indoor air quality
IPMVP	International Performance Measurement and Verification Protocol
kBtu	thousand british thermal units
kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design

M&V	measurement and verification
MACRS	Modified Accelerated Cost Recovery System
MMBtu	million british thermal units
CMH	ceramic metal halide
N	number of years in analysis period
NAESCO	National Association of Energy Service Companies
NEMA	National Electric Manufacturers Association
NPV	net present value
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
OA	outside air
OPR	owner project requirements
ORNL	Oak Ridge National Laboratory
OV	operational verification
PECI	Portland Energy Conservation Inc.
PNNL	Pacific Northwest National Laboratory
PSZ	package single zone DX rooftop unit
RC_x	retrocommissioning
$R_{esc,elect}$	fuel price escalation rate for electricity
$R_{esc,gas}$	fuel price escalation rate for natural gas
RMI	Rocky Mountain Institute
$R_{tax,inc}$	federal corporate income tax rate
RTU	rooftop unit
SAT	supply air temperature
SHGC	solar heat gain coefficient
SV	savings verification
t	years after initial investment
TAB	testing, adjusting, and balancing
VAV	variable air volume
VSD	variable speed drive

Foreword: How To Use This Guide

The AERG for Grocery Stores is one of five retrofit guides commissioned by the U.S. Department of Energy. By presenting general project planning guidance as well as more detailed descriptions and financial payback metrics for the most important and relevant energy efficiency measures (EEMs), we believe these guides provide a practical roadmap for effectively planning and implementing performance improvements in existing buildings.

The AERGs are designed to address key segments of the U.S. commercial building stock: retail store, office buildings, K-12 schools, grocery stores, and healthcare facilities. The guides' general project planning considerations are applicable nationwide; the energy and cost savings estimates for recommended EEMs were developed based on energy simulations and cost estimates tailored to five distinct climate zones. The results of these analyses are presented for individual measures, and for packages of recommended measures for two project types: existing building commissioning, and whole-building retrofits. An overview of the structure of the AERGs is shown below.



This AERG was created to help grocery store decision makers plan, design, and implement energy improvement projects in their facilities. It was designed with energy managers in mind, and presents practical guidance for kick-starting the process and maintaining momentum throughout the project life cycle. The guide was developed primarily as a reference document, allowing energy managers to consult the sections that address the most pertinent topics, without reading the guide from cover to cover. Many other useful guides have been developed by other organizations, and are cited throughout this document when appropriate. This guide endeavors to provide a comprehensive range of information tailored specifically to the needs of small grocery stores and large-chain supermarkets, with an emphasis on the most effective retro-commissioning and retrofit measures as identified by experienced retrofit experts familiar with the special opportunities and challenges associated with grocery stores. This guide presents a broad range of proven practices that can help energy managers take specific actions at any stage of the retrofit process, resulting in sustainable energy savings for many years to come.

The primary sections of the guide are shown in the table below, along with indicators to help stakeholders determine the most relevant sections. All sections should be helpful to energy managers, facility managers, and other corporate staff with responsibilities for planning and overseeing facility improvements that affect energy use. But an effective grocery store retrofit project requires the support of many stakeholders, particularly when the project can positively impact sales and customer satisfaction. The sections of greatest relevance to each audience are indicated in the table below.

	Energy Manager	Facility Manager	Financial Manager/Owner	Utilities and Auditors
1 Introduction	●	●	●	●
2 Overview: Plan, Execute, Follow-up	●		●	
3 Existing Building Commissioning	●	●		●
4 Building Retrofits	●		●	●
5 Measurement and Verification	●	●		
6 Operations and Maintenance	●	●		
7 Conclusion	●	●	●	●

Update to Guide-June 2013

This update to the AERG includes a few changes to the example building cash flow analysis that better align the expected financial payback of certain measures (including the installation of doors on open refrigerated cases) with documented case studies. As a result, the recommended packages for the example building have been revised. Please note that the example building analysis is provided for illustrative purposes only, and feasibility in actual applications should be accessed using case-specific data.

We hope this AERG will be a valuable resource to all grocery store energy managers, facility managers, owners, and other decision makers who seek to improve their buildings, save energy, increase profits, and provide an enhanced shopping environment.

1 Introduction

The U.S. Department of Energy (DOE) developed the Advanced Energy Retrofit Guides (AERGs) to provide specific methodologies, information, and guidance to help energy managers and other stakeholders successfully plan and execute energy efficiency improvements. Detailed technical discussion is fairly limited in these guides. Instead, we emphasize actionable information, practical methodologies, diverse case studies, and unbiased evaluations of the most promising retrofit measures for each building type. A series of AERGs is under development, addressing key segments of the commercial building stock. Grocery stores were selected as one of the highest priority sectors, because they represent one of the most energy-intensive market segments. The energy cost intensity for grocery stores is nearly $4.00/ft^2, ranking just behind the food service industry (see Figure 1–1). For electricity alone, grocery stores spend an average of $3.70/ft^2 (see Figure 1–2). These values are significantly higher in locations with high electricity prices, such as the Northeast and California. Energy expenses rank just behind labor costs as the largest segment of the annual operating budget (EPA 2008).

Section 2 provides an overview of important steps to help energy managers identify energy efficiency improvement opportunities and to successfully plan, implement, and evaluate any level of energy upgrade project. We then address specific planning stages in subsections about performance assessment through benchmarking, identifying cost-effective measures (see sidebar) through energy auditing, and financing mechanisms.

Section 3 provides a detailed discussion of existing building commissioning (EBCx) measures that should be considered as the first step in almost any grocery store upgrade project. The descriptions cover energy and cost savings, special opportunities and challenges, and climate-dependent considerations. Section 4 provides recommendations for going further with specific retrofit measures, addressing the strengths and weaknesses of each, and providing energy savings and cash flow analyses for recommended packages.

Sections 5 and 6 provide guidance for verifying and sustaining energy savings through measurement and verification (M&V) and operations and maintenance (O&M). The purpose of M&V is to make sure the improvements are implemented properly, and achieve the expected level of energy savings. M&V is usually performed by examining utility bills and making direct measurements of energy use for important subsystems. O&M is a process for managing the operation of improved systems to ensure that the initial energy savings are not undermined over time through improper use or inadequate maintenance.

This guide to building energy retrofits offers practical methodologies, diverse case studies, and objective evaluations of the most promising retrofit measures for grocery stores. By combining modeled energy savings and estimated costs, this guide presents cost-effectiveness metrics for individual measures and for recommended packages of measures. This information can be used to support a business case for energy retrofit projects and improve the energy performance of buildings nationwide.

Barriers addressed by this guide:

- Difficulty getting started
- Limited capital and competition for resources
- Shortage of actionable information tailored to grocery stores
- Failure to consider all benefits over project life
- Lack of specific integrated design methods adapted to grocery store retrofits
- Need for reliable data to support business case
- Desire to minimize risk

Cost-effective measures: In the context of this guide, we define cost-effective measures as those with a positive net present value, as discussed in Section 2.6 and Appendix A.

We also include case studies that show how other stores and supermarket chains have implemented energy upgrades, the savings they have achieved, and the challenges they have faced. These case studies are distributed throughout the guide to illustrate the applications of key points.

Integrated design: A collaborative and iterative design process for building improvements in which a systems approach is employed to leverage multiple energy and nonenergy benefits from a capital improvement project, resulting in much higher energy savings than can be achieved using a piecemeal approach.

Why do we need another retrofit guide when a great deal of information is already available? Our goal is to address one of the biggest gaps in the literature: reliable and actionable cost and energy savings methods and data in the context of grocery stores. This guide helps to fill that gap by providing comprehensive analytical methods for evaluating the cost effectiveness of potential retrofit measures. In the context of this guide, cost effective is synonymous with positive net present value (NPV) based on incremental cash flows over a 20-year analysis period, whether referring to a single measure or a package of measures. NPV analysis assumptions will be discussed in greater detail in Section 2.6 and Appendix A. These analytical methods are supplemented with a comprehensive and detailed example using the Pre-1980s Grocery Store Commercial Reference Building (CRB) developed by DOE (Deru et al. 2011b). The example represents a relatively old grocery store, with equipment that has been replaced at least once since the store was built. The optimal packages for other grocery stores will vary significantly, but the example illustrates the application of measures and methodologies described in the guide.

Because of the wide variation in the building conditions and financial constraints on grocery stores, three types of building upgrades are addressed in this guide: (1) low-cost and no-cost EBCx measures; (2) whole-building retrofits where a comprehensive package of measures is implemented in a short span of time using an integrated design approach (see sidebar); and (3) staged retrofit projects that leverage energy savings from each stage and more opportune timing of retrofits to achieve similar savings in an incremental fashion.

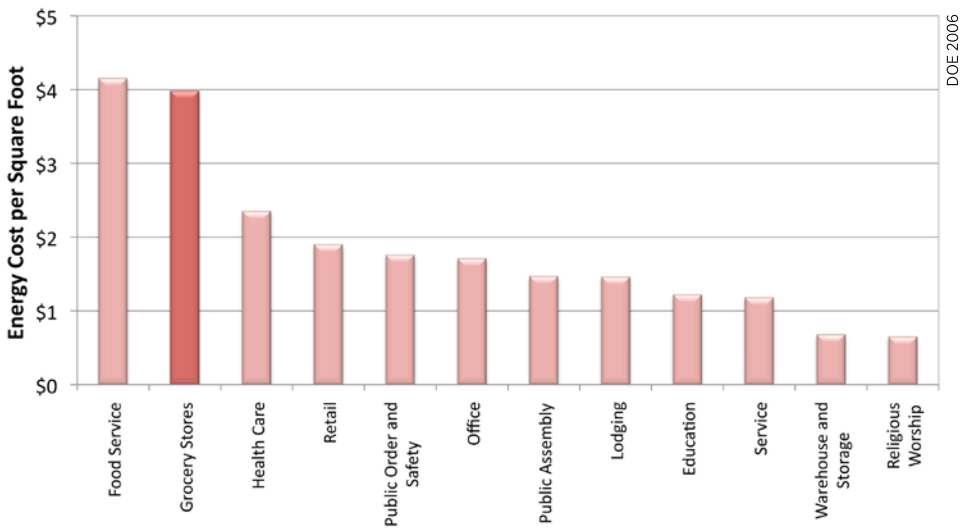


Figure 1–1 Energy cost intensity for common commercial buildings

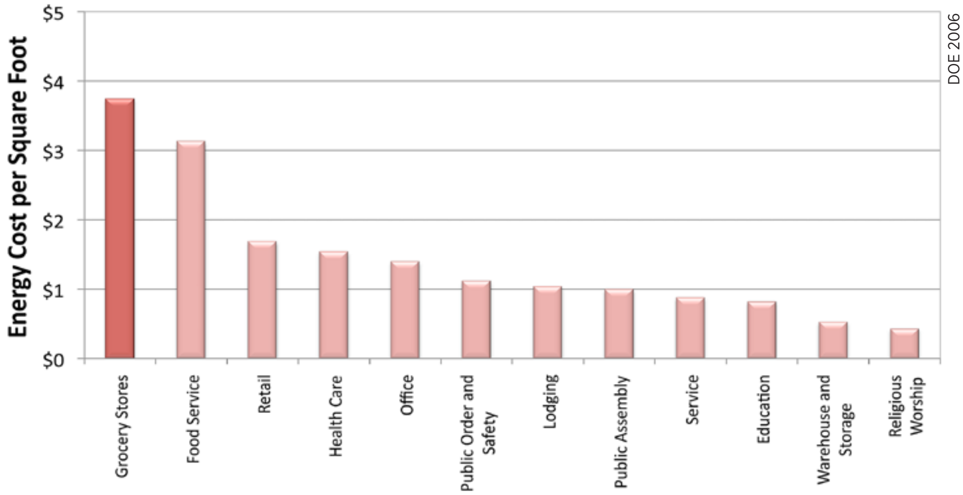


Figure 1–2 Electricity cost intensity for common commercial buildings

1.1 Purpose and Audience

The overall purpose of this AERG is to increase the number of retrofit projects in the grocery store building sector, and enhance the quality and depth of energy savings for those projects. The material offered in the guide is designed to increase market uptake of high-impact, cost-effective improvements by providing objective, actionable information tailored specifically to the unique opportunities and constraints associated with grocery stores and supermarkets. In recognition of possible financial constraints and wide variations in the characteristics of existing stores, we address several retrofit approaches to provide greater flexibility to develop effective building improvement projects in a broad spectrum of situations.

The primary audience for this guide is grocery store energy managers or facility managers who wish to significantly increase the efficiency of an individual grocery store or an entire chain of stores, and generate a strong financial return that can increase profit margins or be reinvested in other areas. Several additional stakeholders will benefit from specific sections of this guide, as summarized in Figure 1–3 and described in more detail in the following subsections.

	Energy Manager	Facility Manager	Financial Manager/Owner	Utilities and Auditors
1 Introduction	●	●	●	●
2 Overview: Plan, Execute, Follow-up	●		●	
3 Existing Building Commissioning	●	●		●
4 Building Retrofits	●		●	●
5 Measurement and Verification	●	●		
6 Operations and Maintenance	●	●		
7 Conclusion	●	●	●	●

Figure 1–3 Relevant sections for grocery store stakeholders

Energy Manager

The energy manager, or the decision maker with equivalent responsibilities, must develop a strong justification for retrofit projects, and requires sound economic and technical analysis methods and data before committing financial resources to a project. He or she also oversees a project's successful implementation. The entire guide is targeted to this audience, and is designed to provide practical guidance at each stage of the retrofit process.

Facility Manager

The facility manager has an important role in implementation, verification, and maintenance of the measures discussed in this guide. In fact, many of the commissioning measures described in Section 3 can be performed in the normal course of routine maintenance activities, with no major capital investments that require special approval. The facility manager may also be interested in the sections describing good practice for M&V and O&M. In many cases, the facility manager may have the role of energy manager for a store, in which case the entire guide will be of value.

Building Owner or Financial Manager

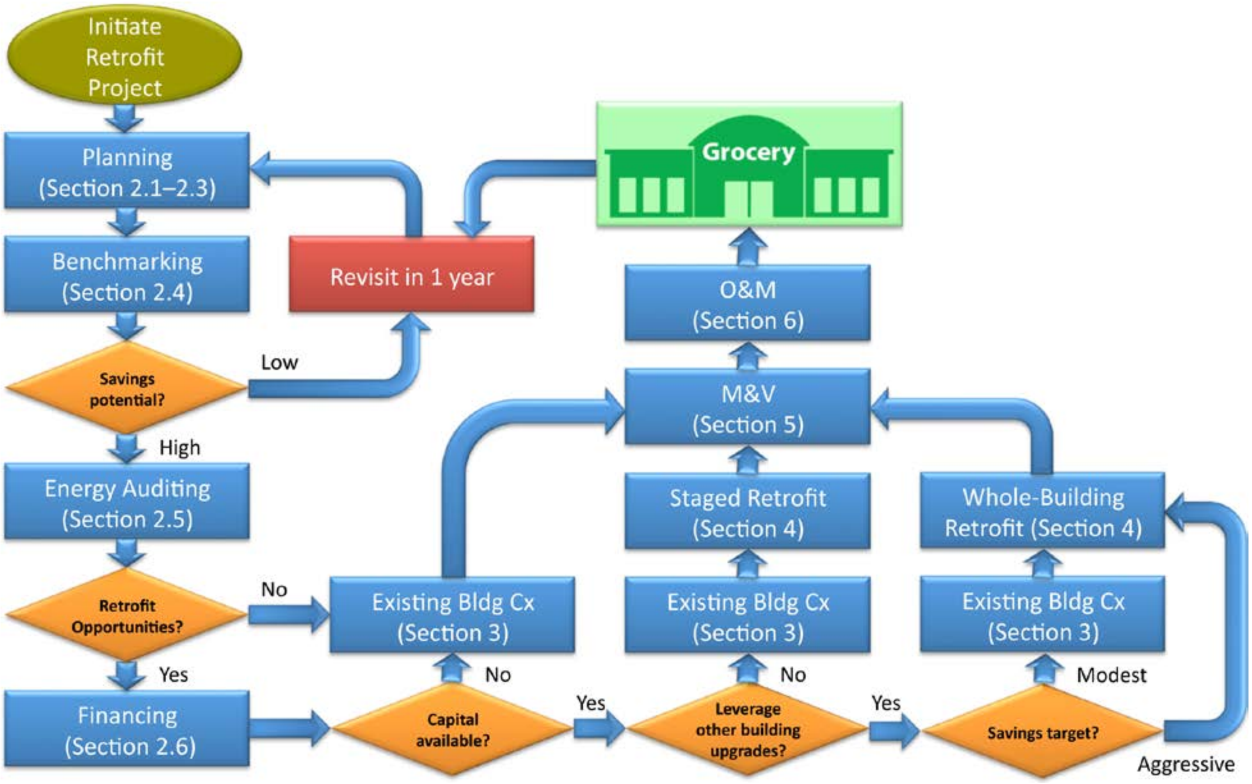
The building owner or financial manager has essential responsibilities for authorizing and overseeing major capital investment projects, and must ensure the financial health of the store. Many planning and financing decisions related to retrofit projects must be made or approved by the financial manager, and the information described in Section 2 is designed to assist with that process. The financial manager may also be cognizant of necessary building renovations or other leveraging opportunities that create the potential for a more aggressive retrofit package.

Utilities and Auditors

The prioritized commissioning and retrofit measure descriptions provided in Sections 3–4 and Appendices E–G can help stimulate ideas for even experienced auditors, utility companies, and retrofit contractors. Grocery store retrofit experts from across the country provided their insights and knowledge to identify the most important measures that should be evaluated for any project, and to describe the strengths, weaknesses, climate considerations, and application issues for each measure in the context of grocery stores.

1.2 Structure of the Guide

This guide is most useful during the initial stages of a retrofit project, but it also serves as a valuable reference throughout the life of a project by stimulating ideas for additional retrofit measures, describing important performance and cost tradeoffs, and identifying reliable M&V protocols. Figure 1–4 shows how each section fits into the general process of upgrading a grocery store. The sequencing shown in Figure 1–4 illustrates a common approach to addressing retrofits, and is consistent with the order of topics in this guide, but alternate sequencing and additional steps may be included depending on the situation. The planning and implementation process will be explained more fully in Section 2.



Credit: Bob Hendron/NREL

Figure 1–4 Structure of the guide relative to a typical retrofit decision-making process

This AERG provides guidance and example energy efficiency packages for achieving a high level of energy savings in grocery stores. A strict minimum energy saving cannot be guaranteed, because of the range of potential starting points, but we identify multiple low-risk (see sidebar) EBCx and retrofit measures that are expected to meet strict cost-effectiveness requirements based on an example building that is representative of the stock of grocery stores across the United States.

Three categories of retrofit are discussed in the following sections, and summarized in Table 1–1. Example measures for each category are provided in Figure 1–5.

Risk: We define *risk* as uncertain return on investment caused by variations in energy savings, installation costs, useful life, or O&M costs.

Table 1–1 Three Categories of Retrofit Discussed in This Guide

EBCx
Significant savings can often be achieved with minimal risk and capital outlay by improving building operations and restructuring maintenance procedures. This process is generally recommended even when retrofits are being considered, in order to determine the performance of the existing building systems under the most favorable conditions. A study of 643 commercial building commissioning projects by Lawrence Berkeley National Laboratory (LBNL) indicated that approximately 12% energy savings could be achieved in a typical grocery store, with an average payback period of 0.3 years (Mills 2009). Savings well in excess of 30% can be achievable if a store has particularly severe O&M weaknesses. Additional savings are possible if cultural and behavioral changes are included.
Whole-Building Retrofit
Whole-building retrofit projects use an integrated design approach to develop a package of measures that can be implemented as a single project over a short period of time. Often this approach leverages a major remodeling effort or a similar opportunity to address many systems at once. Whole-building retrofits offer greater potential savings because the package is optimized and all systems interactions are considered. Systems interactions and equipment downsizing are important components of this approach, and broader ranges of equipment replacements and envelope upgrades are often possible. In many situations, the best packages for whole-building retrofits will be very similar to the prescriptive packages recommended for new construction in the Grocery Store 50% Energy Savings Technical Support Document developed by the National Renewable Energy Laboratory (NREL) (Leach et al. 2009). NREL's work with two SuperTarget stores indicates that about 15% additional savings could be achieved through an integrated design approach compared to a retrofit project where only component and subsystem level improvements were possible (DOE 2012). In an LBNL study of 1,634 retrofit projects conducted by energy service companies (ESCOs), which primarily consist of government facilities such as federal office buildings and local schools (Hopper et al. 2005), median energy savings of about 18% were documented, but savings beyond 25% were common. Simple payback was typically 10 years or less for most projects, which is validated through the example analysis presented in Section 4. Grocery stores are likely to have more stringent financial payback requirements than publicly owned buildings, but there are likely to be a greater number of energy saving opportunities when grocery store refrigeration systems are considered. In addition, many projects in the LBNL study were targeted system- or component-level retrofits that did not include an integrated whole-building approach.
Staged Retrofit
Staged retrofits are implemented in several steps over a longer period of time than whole-building retrofits. This approach allows retrofits to be aligned more closely with the store's capital improvement plans, reducing the incremental cost of the upgrades because equipment replacements occur near the end of useful life. An integrated design approach is recommended even for staged retrofits, but it can be more challenging to properly exploit systems interactions when a period of time passes between stages. It is important to plan all retrofits early in the process, even though they are implemented over time. This will help mitigate inefficiencies created if new contracts must be placed and different personnel are involved later. Some potential energy savings are delayed in a staged retrofit, but the economics can be much better than for a whole-building retrofit, where equipment with a significant amount of useful life remaining may be replaced.

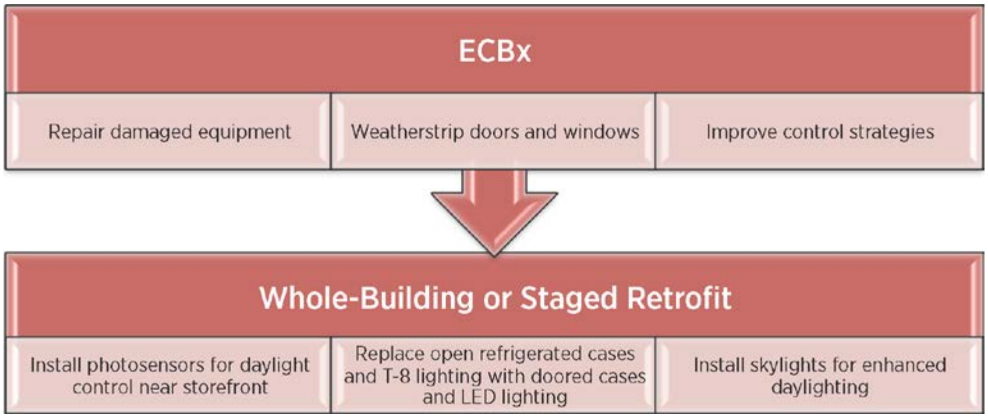


Figure 1–5 Example measures for the two categories of building improvements addressed in this guide

An energy manager can use several core elements as components of a strong business case for upgrading a single grocery store or an entire portfolio:

- General guidance describing important steps to help energy managers identify opportunities and successfully plan, design, implement, and verify the energy savings for retrofit projects in grocery stores. Because other organizations have already provided such guidance, we provide concise summaries of alternative approaches and reference published handbooks, standards, websites, and software tools extensively.
- Descriptions of approximately 70 promising EEMs, including a short overview of each and how it can be applied to a typical grocery store. Many additional measures are addressed in the context of integrated subsystem improvements for more comprehensive retrofit projects. Climate-specific considerations are discussed, along with other factors such as store size, hours of operation, mechanical system type, and vintage. Special opportunities related to the age, condition, and efficiency of existing equipment are also discussed.
- Recommended packages of EBCx and retrofit measures for a representative grocery store, tailored to five important U.S. climate regions.
- Key leverage points during the life cycle of a store that offer special opportunities to cost-effectively achieve more aggressive energy savings targets. These catalyst opportunities include any situation that leads to major changes in building systems for nonenergy reasons, such as a change in building use (e.g., a general retail store converted to a grocery store), replacement of malfunctioning equipment, or major remodeling for aesthetic or functional reasons.
- Techniques to ensure that the expected level of energy savings is achieved following the retrofit, and persists throughout the life of the equipment. These strategies include post-retrofit commissioning, optimizing control logic, establishing equipment set points, involving and educating employees, ensuring that service technicians return equipment to the correct performance levels following repairs, good practices for ongoing commissioning and maintenance, and the most appropriate M&V protocols at each energy savings level.
- A diverse set of case studies that provide real-world examples of how these recommendations have been implemented in actual retrofit projects. The case studies are accessible and objective, offering insights into the opportunities, tradeoffs, and potential pitfalls that will be encountered in a retrofit project. To the extent possible, actual cost, performance, and utility billing data have been included. Detailed case studies are essential to an effective business case, because evidence that similar projects have been successful enables financial decision makers to fund projects with greater confidence.

1.3 Business Case

Among the investments a grocery store owner may consider, energy efficiency upgrades are likely to offer some of the highest returns with the lowest risks (i.e., low likelihood that energy savings will not be realized). The direct cost reductions provided through reduced energy use are complemented by valuable nonenergy benefits. The primary drivers for most grocery store owners to invest in energy efficiency are to realize the direct benefits of reduced utility costs and to improve the shopping environment for customers. Considering only the economics of a retrofit potentially misses enormous value beyond the cost savings. In grocery stores, this value can be an improved sales environment and better community and national stature. According to a Deloitte and Lockwood (2009) study, “many businesses that are taking on green retrofits are doing so to achieve market rather than cost structure objectives.”

Grocery store energy and facility managers are continuously balancing the demands of owners for reduced operating costs and higher sales. They also often consider interior remodels to ensure customers feel the store is fresh and up to date. Yet more than 1,700 grocery stores (which represent nearly 83 million ft^2) have earned the ENERGY STAR® label, and those numbers continue to grow (ENERGY STAR 2011). In the near future, a grocery store that has not improved its energy efficiency may seem out of date to customers and a less desirable place to shop.

Funding is often the primary barrier to the implementation of retrofit projects in grocery stores. The financial decision maker needs reliable cost and energy savings data to evaluate cost effectiveness and risk as part of a solid business case, and decide between a whole-building and a staged retrofit. Practical analysis techniques and meaningful data are not easily found in the literature, especially in the context of specific building types, but are essential tools for robust and accurate analysis of energy and cost tradeoffs. In contrast, this guide provides a clear methodology for performing accurate economic analysis of building improvement options using both NPV and simple payback period, supplemented with example calculations using a typical grocery store, and detailed case studies with documented project cost and energy savings data.

The guide provides detailed methods for accurately quantifying multiyear cash flows, including energy costs, demand reduction, replacement costs (including reduced energy savings if more efficient equipment would have been required by code), salvage value (if any), O&M costs, M&V costs, and tax implications. Techniques and references are also provided for capturing the effect of temporary financial incentives offered by government agencies or utilities (such as rebates, low interest loans, and tax credits) on multiyear cash flows. Indirect benefits such as productivity improvements and reduction in sick days are discussed qualitatively, but are not quantified in the cash flow analysis. Advice is provided for developing a comprehensive capital replacement plan, which is a necessary component of any multiyear cash flow analysis.

This guide does not provide detailed instructions for developing an effective business case for a retrofit project. Instead, we focus on specific measures, methodologies, and examples that contribute to a strong business plan. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recently published an informative resource for business case development titled, *Energy Efficiency Guide for Existing Commercial Buildings: The Business Case for Building Owners and Managers* (ASHRAE 2009). It is the first of a series of three ASHRAE technical guides that describe best practices for planning and implementing successful energy retrofit projects. Other valuable tools and resources for developing a business case and analyzing the economics of a retrofit project are discussed in Section 2.6.

1.4 Recommended Packages

We developed EEM packages for EBCx and whole-building retrofit projects in the context of an example grocery store. To be selected, measures must have a positive NPV when cash flows are analyzed over a 20-year period. A spreadsheet tool was created by NREL and PNNL to assist with the multiyear cash flow analysis needed for NPV and simple payback calculations.

A 20-year time horizon was selected because we encourage decision makers to take a longer term approach to energy efficiency improvements than is typically applied to grocery store investments. Because most equipment improvements have lifetimes shorter than 20 years, this analysis period includes at least one replacement of each measure except envelope improvements, resulting in a more stable projection of NPV than would result from a short-term analysis. In addition, energy and maintenance savings often extend far beyond the simple payback period, which may be as short as 3–5 years. The same methodology can be used even if stricter financial return and payback criteria must be used, with minor changes to the input parameters. It can also be applied to staged retrofits, although we did not develop recommended packages for the staged approach because the analysis is more complex and is highly dependent on the age of existing equipment and the capital improvement plan.

Selected packages range from low-cost/no-cost EBCx packages that are nearly always cost effective, to more capital-intensive retrofit packages with somewhat higher risks but larger life cycle returns. These packages serve as examples that illustrate the analysis methodologies discussed in this guide, and provide some sense of the energy savings that are achievable in a typical grocery store.

Unlike the recommended packages for new construction in the *Advanced Energy Design Guides*, the recommended packages are not prescriptive in nature and are not evaluated against a code-minimum building. Because of the diverse range of starting points for a retrofit project and the limited applicability of building energy codes, prescriptive recommendations based on cost effectiveness are not possible. A recommended package might provide excellent financial returns in one situation, but would not be optimal or even appropriate in all situations. Your actual cost and energy savings will differ from the example, and you need to analyze the actual cost effectiveness of a particular set of EEMs in the context of the actual building, financing method, labor rates, rebates and tax credits, vendor prices, and utility rates.

Figure 1–6 illustrates the process used to narrow the original list of roughly 178 candidate measures for grocery stores to those included in the recommended packages. About 58 measures from the original list were deemed to save very little energy, or were considered unlikely to be cost effective, and were therefore dropped from consideration. Approximately 120 measures were considered high potential, and are addressed in Sections 3–4 and Appendices E–G. About 60 were considered for the recommended packages. The complete list of measures and their rankings are included in Appendix D.

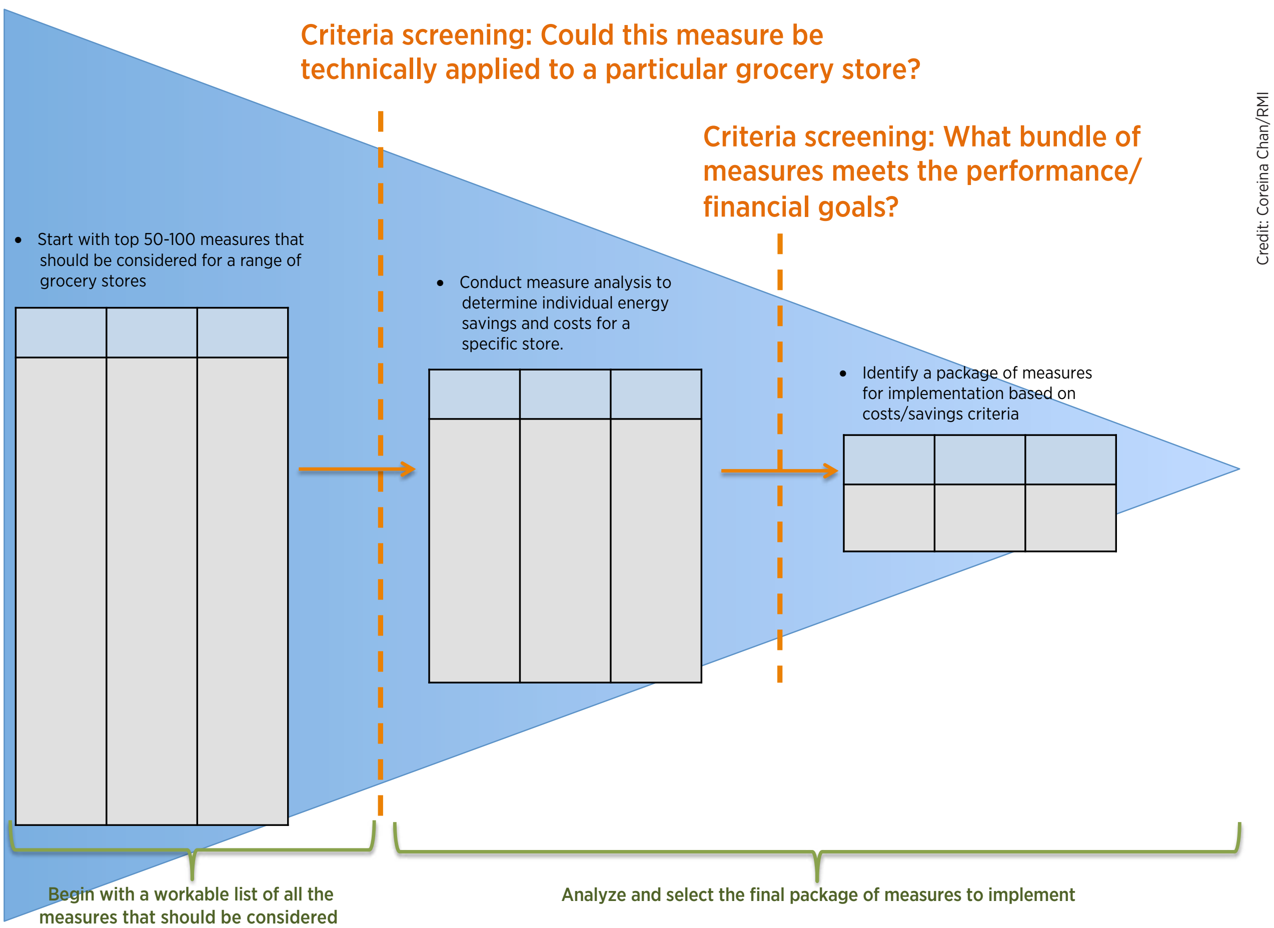


Figure 1–6 General process for selecting measures included in recommended packages

The reference building for our example analysis is the Pre-1980s Grocery Store Commercial Reference Building (CRB) (Deru et al. 2010), which is one of a series of reference buildings developed by DOE to help standardize the analysis of EEMs when applied to specific building sectors. Details of the envelope characteristics and equipment included in the example building are presented in Appendix B.

The CRB was tailored to each of five important U.S. climate regions (see Figure 1–7), represented by the city in parentheses:

- Hot-humid (Miami, Florida)
- Hot-dry (Las Vegas, Nevada)
- Marine (Seattle, Washington)
- Cold (Chicago, Illinois)
- Very Cold (Duluth, Minnesota)

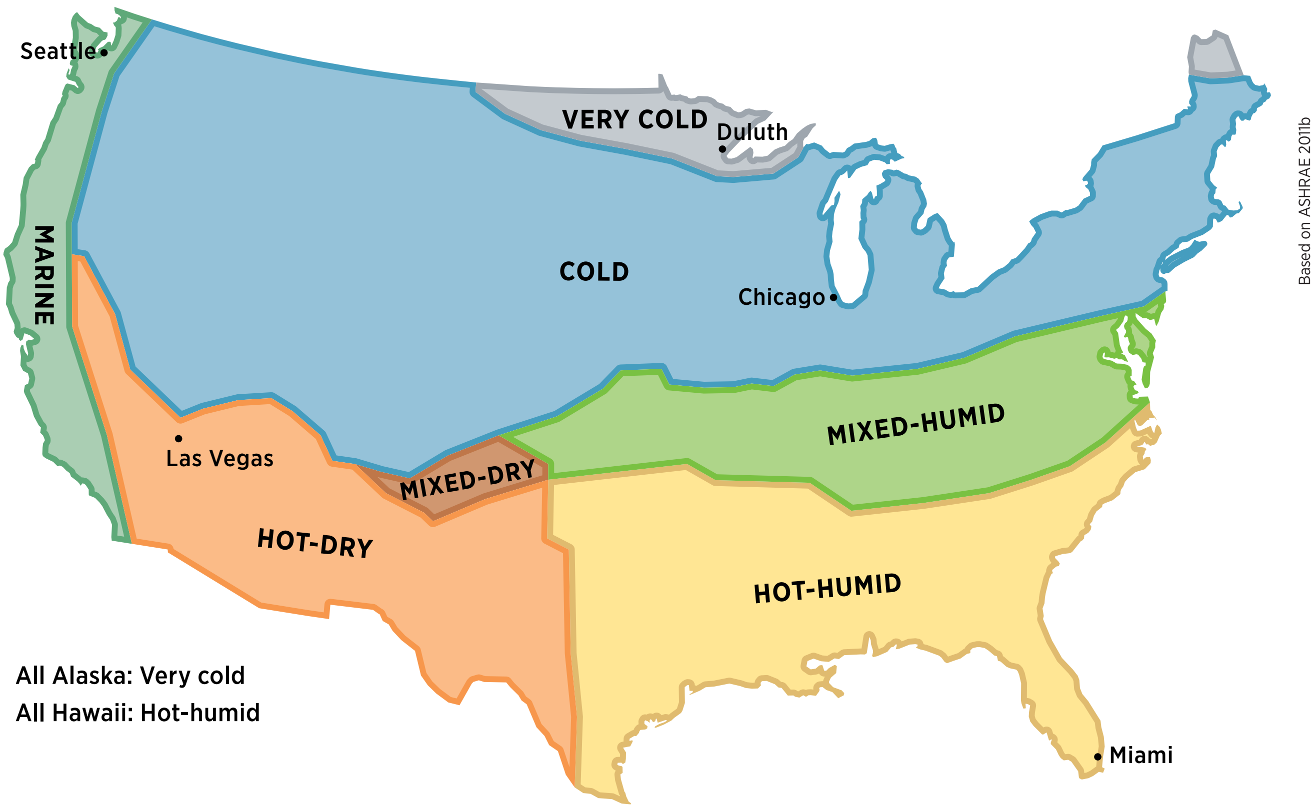


Figure 1–7 U.S. Climate Zone map

The DOE CRBs are assumed to be well commissioned. The modeling inputs inherent in the CRBs are not consistent with suboptimal operating schedules, building controls that are no longer active, or degraded equipment performance caused by wear and tear. As a result, we did not try to model EBCx measures. Instead, the recommended EBCx packages were developed based on subjective estimates of the likely energy savings of each measure considered. We estimated energy savings for the EBCx package based on data from actual projects, combined with the CRB physical characteristics and energy use. Further details about the process for selecting EBCx packages are provided in Appendix B.

The measures included in the recommended retrofit packages were chosen based on the cost effectiveness of each measure when applied to the CRB model, using typical equipment costs and actual utility rates. Each measure was analyzed individually and in combination with other measures when system interactions were large. This sequencing allowed for the possibility of downsizing heating, ventilation, and air-conditioning (HVAC) equipment due to reduced heating and cooling loads. Measures were selected for the recommended packages if their individual NPVs were greater than zero. Additional discussion of the process used for selecting retrofit measures for the recommended packages is included in Appendix B.

2 Overview: Plan, Execute, Follow Up

Industry leaders have long recognized the role that energy efficiency can play in reducing operating costs, increasing asset value, and improving the shopping experience. Opportunities for improved energy performance exist in nearly every grocery store. These come in many forms, including improved O&M practices, equipment retrofits, occupant behavioral changes, and building envelope modifications. Over the life of a building, different opportunities will be available at different times, depending on the changing uses of a building, remaining life of the equipment and assemblies, and availability of improved technologies in the market.

Although the opportunities for energy efficiency improvements in existing grocery stores are significant, the process of identifying, analyzing, and implementing those improvements is not always straightforward. This section provides an overview of important steps to help identify energy efficiency improvement opportunities and plan their implementation. It addresses plotting an energy efficiency roadmap, available financing mechanisms, performance assessment through benchmarking, and identifying cost-effective measures through energy auditing (see sidebar in Section 1.0 for our definition of cost-effective measures). Each section includes links to the extensive body of literature about these topics to provide more details.

2.1 Energy Picture

Supermarkets and grocery stores have enormous appetites for energy—they use more than 50 kWh/ft^2 of electricity and 38,000 Btu/ft^2 (0.038 decatherms/ft^2) of natural gas per year, making them the second most energy-intensive consumer in the commercial sector after food service (DOE 2006). The good news is that the cost- and energy savings opportunities available to this sector are also substantial. Implementing energy efficiency upgrade projects in supermarkets and grocery stores presents unique challenges and opportunities to save energy while enhancing product visualization, ensuring customer comfort and satisfaction, and preventing food spoilage. To achieve maximum return on investment for energy efficiency projects, energy managers need to know how energy affects the grocery products and consumers, how and where energy is used, and what options are available to reduce energy use. Assistance is available from utilities and other organizations to help supermarkets take advantage of the opportunities and overcome the challenges.

Opportunities and Challenges

The energy intensity of grocery stores is increasing as consumers demand more fresh food products, stores expand their frozen food aisles, and regulations impose more stringent food temperature requirements. In addition, aesthetics and customer comfort play an important role in attracting and maintaining business, which puts additional strains on HVAC systems to maintain temperatures in conditioned spaces. Increasing the challenge, grocery stores typically operate with small profit margins, which means that they often have limited resources for implementing EEMs and generally require a quick payback for any projects they undertake. Opportunities for energy and cost savings include improving equipment efficiency, minimizing waste, and reducing loads during peak times. An energy upgrade can also provide many nonenergy benefits, including increased profitability, increased sales, improved food safety, reduced spoilage, and an enhanced public image.

Increased profitability

Energy costs account for 15% of a supermarket's operating budget (ORNL 2003). Reducing energy costs by 10% is equivalent to increasing net profit margins by 16% and sales per square foot by $50, according to the U.S. Environmental Protection Agency (EPA) (EPA 2008). For large supermarket chains, this can add up to millions of dollars.

Increased sales

Cost-effective energy upgrades to stores usually involve improvements to the lighting and HVAC systems, which improves the thermal and visual environment. An aesthetically pleasing environment, with appropriate illumination and comfortable temperatures, is important for attracting and retaining customers.

Food safety and reduced spoilage

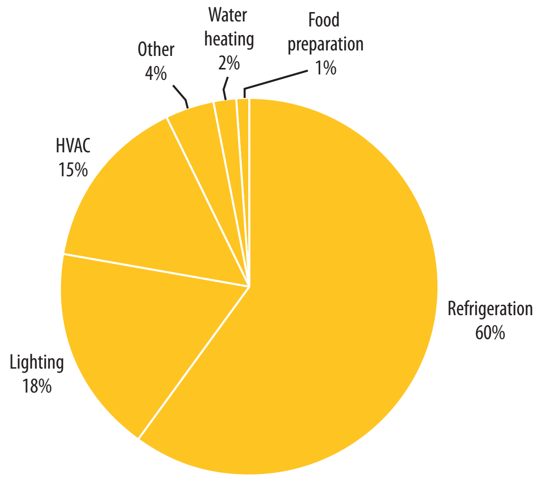
Perishable foods constitute the single largest category within a conventional supermarket chain, contributing to approximately 35%–50% of sales and 40%–55% of gross profits (Food Quality 2007). Upgrades to refrigeration and lighting systems can reduce losses associated with spoilage of perishable goods and save on operational costs and energy bills.

Enhanced public image

With a shift toward customer demand for more local and organic produce—part of a shift to more sustainable living habits—grocery store managers are realizing the marketing benefits of demonstrating responsible environmental stewardship. Implementing energy efficiency upgrades are a part of this strategy. Hundreds of small and large grocery stores participate in the EPA's ENERGY STAR buildings program and have taken steps to improve efficiency and gain recognition for their achievements.

End Use Categories

To target energy-saving upgrades, it helps to know where most energy is used. For individual grocery stores or supermarkets, this is best done by benchmarking and auditing, as discussed in Sections 2.4 and 2.5. For the average grocery store, according to data from the Edison Electric Institute, 78% of electricity used is consumed by refrigeration and lighting systems (see Figure 2–1); space heating accounts for 56% of natural gas consumption (Figure 2–2) (E Source 2008). Another study by the American Council for an Energy-Efficient Economy (ACEEE) showed similar results with refrigeration accounting for 53% of a grocery store's electricity consumption, followed by lighting at 19% and heating at 17% (Hirsch et al. 2010).



© E Source; data from Edison Electric Institute

Figure 2–1 Grocery store electricity consumption by end use

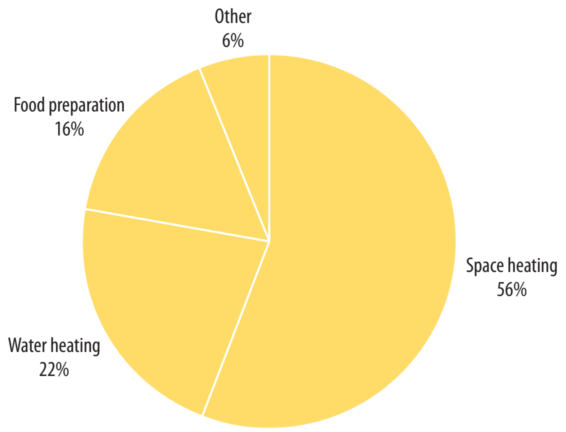


Figure 2–2 Grocery natural gas consumption by end use

2.2 Planning Retrofit Projects

A successful energy efficiency upgrade depends on well-defined goals and a carefully constructed scope. If the goal is simply to cut energy costs by 5%–10%, an EBCx (Section 3) program will probably be sufficient, but even that effort will require benchmarking (Section 2.4) to determine a baseline, a walk-through audit (Section 2.5) to identify the most promising measures for your situation, and M&V (Section 5) to determine whether you have reached your goal. If the goal is to be the top performer in the market, or to have your store outperform other similar stores, the decision process is more complicated, as illustrated by the example decision process flowchart in Figure 2–3.

The retrofit process typically begins with an assessment of the potential energy savings available in a single store or a chain of stores (benchmarking), followed by an evaluation of the cost-effectiveness of possible retrofit measures (energy audit). If significant savings are achievable and cost-effective, sources of financing should be evaluated and energy savings targets should be set. Opportunities for leveraging planned store upgrades should also be considered at this point. Depending on the results of these steps, some combination of EBCx, whole-building retrofits, and staged retrofits are selected. Following implementation of the retrofit project, appropriate M&V and O&M programs are undertaken to ensure that the target energy savings are achieved and persist over time.

Although EBCx is often skipped in a comprehensive retrofit, you may still want to perform this step because it will provide quick savings and will help you determine existing system performance under the most favorable conditions. That information will give you a better handle on what else needs to be done to meet your goals. If, for example, a lighting retrofit is called for, there is no reason not to precede the retrofit with EBCx measures. If it is apparent from the start that a major retrofit effort will be undertaken (for example, a new central refrigeration system will be installed in the near future), it may make sense to postpone some of the EBCx measures—a testing, adjustment, and balancing (TAB) project for example—because the new equipment will have to be commissioned anyway.

The benchmarking effort will help you to quantify your goals by showing you how well the competition is faring. A more comprehensive audit will help you determine which retrofit measures (Section 4) are appropriate for your store. In all cases, the most effective program will also include reviewing for continual improvement:

- Management review of project results
- Modification of energy plan as needed
- Recognition of success

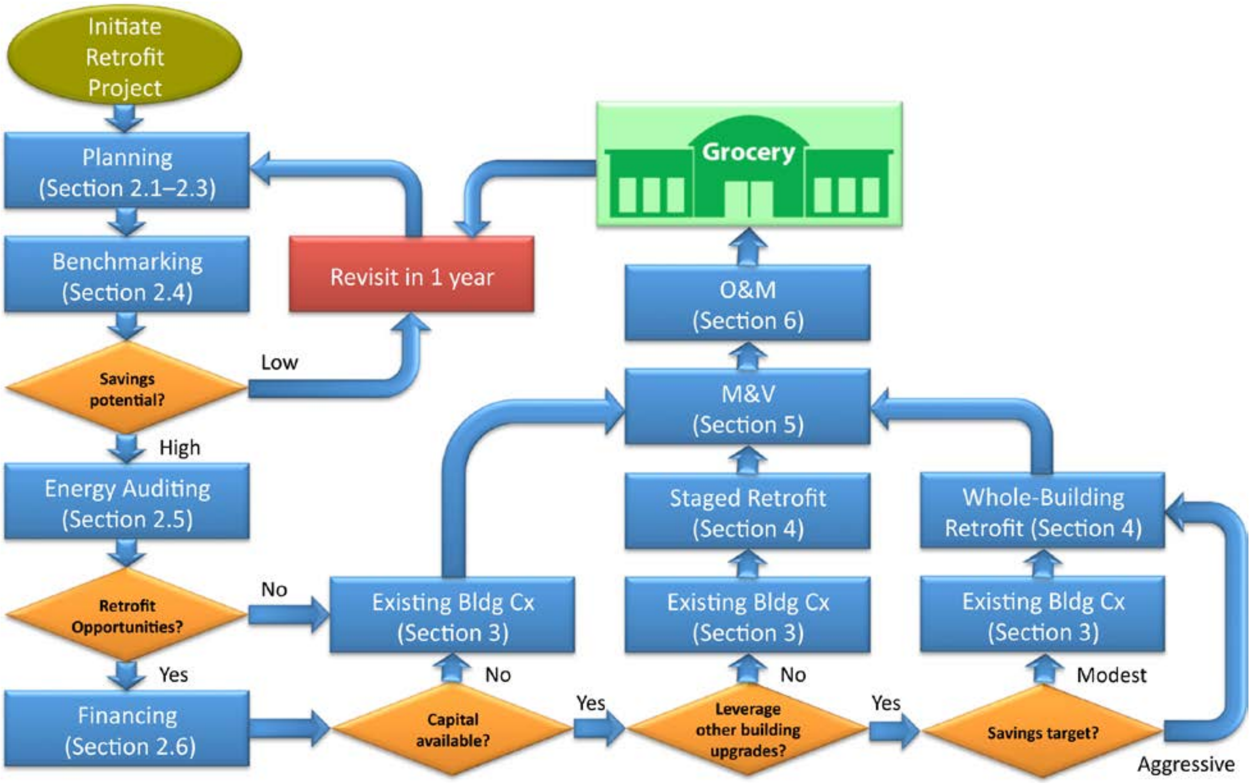


Figure 2–3 Example decision process for a retrofit project

Grocery store and supermarket energy upgrades may be approached on an individual facility basis, but the greatest potential for savings may come from a portfolio-wide or regional approach. This enables supermarket chains to offset costs of more comprehensive energy efficiency projects in buildings that have higher upfront costs with the savings from projects in other buildings. A system-wide approach also generates greater momentum for energy efficiency activities, leading to sustained commitment from management and continued savings, and can provide economies of scale when work is excecuted by the same contractor. Raising awareness in the community about the environmental and cost-saving benefits of a project will help gain additional support, move the project forward, and attract new customers.

The timing of a project depends on several factors, including its size and scope, availability of capital, financing, and incentives. A supermarket chain might implement a comprehensive whole-building project to take advantage of incentives from government or local utilities. A supermarket might also implement upgrades in stages, leveraging cost savings from initial energy efficiency improvements to pay for additional measures. In cases where resources, such as funding and personnel, are not available, supermarkets can apply the upgrade concepts to one or a few stores. Successful outcomes can then be used to make a business case for further improvements, covering a broader range of buildings, when additional support and resources become available.

Whole-Building Versus Staged Approach

Whole-building retrofit projects most often use an integrated design approach to develop an EEM package that can be implemented as a single project over a short period of time. Often this approach leverages a major remodeling effort or a similar opportunity to address many systems at once. Further discussion of the whole-building retrofit approach is provided in Section 4.1.

Staged retrofits are implemented in several steps over a longer period of time than whole-building retrofits. This approach allows retrofits to be aligned more closely with the store's capital improvement plans, reducing the incremental cost of the upgrades because equipment replacements most often occur near the end of their useful lives. An integrated design approach is recommended even for staged retrofits, but it can be more challenging to properly exploit systems interactions when a period of time passes between stages. Additional guidance for implementing a staged retrofit is presented in Section 4.2.

2.3 Key Steps in the Retrofit Process

Planning and implementing a successful upgrade project involves several steps, which include making a commitment, assessing performance through energy audits and benchmarking, evaluating financing options, implementing the project, evaluating its progress, and developing an O&M program to ensure savings persist.

Get Started

A grocery store upgrade project will get off to a quick start if there is commitment from senior management and decision makers to a policy for continuous improvement. This helps to secure adequate funding and gain staff support. A committed team or individual champion can initiate, lead, and implement the energy efficiency project. This person or team will guide the effort, keep it on track, make sure there are no bureaucratic roadblocks, provide access to data, justify the project to decision makers, and oversee project implementation. Identifying team members throughout a supermarket chain who will lead an energy efficiency project will help to ensure quality and broad support. Defining and implementing an energy policy with clearly stated goals can help secure support from owners and decision makers and will be valuable in tracking and verifying efficiency improvements. For example, one of the nation's largest grocers, Kroger, has designated an energy champion at each store to look for ways to cut energy use and educate fellow employees. This has helped the chain cut energy use by 27% since 2000 (Kroger 2010). Another example is illustrated in Case Study #1, which shows how Whole Foods Market is progressing toward its commitment to reduce energy use 25% by 2015.

At times, the objectives for a grocery store may seem to be at odds with, or in competition for, funding, such as improving product display and reducing energy consumption. Often, improving display means shining more light on the product and using more energy. However, reducing all ambient light and accenting products to create a similarly attractive brightness could achieve both objectives. It is critical for facility managers and other stakeholders to express their full range of objectives and concerns to the project team, who can then design solutions that meet the objectives at least cost and for multiple benefits.

Case Study 1: Whole Foods Market

Quick Facts

- Facility Name: Whole Foods Market
- Facility type: Supermarket
- Location: Fresno, California
- Gross square footage: 30,800

Whole Foods Market has maintained a focus on reducing energy costs and the associated environmental footprint of its store operations for a number of years. One typical example is its store in Fresno, California.

In October 2008, night covers were installed on all vertical, open display cases at the store. This helped reduce the load on the refrigeration system caused by warm air infiltrating into the cases. Even after factoring in the labor required to pull the strip curtains down each night, it was determined that the energy savings would be cost effective.

> *"Whole Foods Market has set a goal of reducing energy intensity by 25% by the year 2015. The upgrades implemented at our Fresno store will help contribute to that goal."*
>
> — Gary Fine, Energy & Maintenance Coordinator

In the next stage, highly efficient, electronically commutated evaporator motors were installed in the store's refrigerated display cases and walk-in storage units. Then, Source Refrigeration, a refrigeration contractor with controls expertise, updated the refrigeration control system to allow floating head and suction control strategies to be implemented.

Courtesy Whole Foods

An analysis of the store's utility bills indicate that this three-month retrofit project saved more than $30,000 in the first year alone. Per Gary Fine, the regional Energy & Maintenance Coordinator, the retrofit at Fresno is part of the company's goal to reduce its energy intensity by 25% by 2015. Whole Foods Market will continue to explore and implement cost-effective approaches to reducing energy consumption at its Fresno, California, location and its other stores across the country in pursuit of that goal.

Key Measures

1. *Night covers on open vertical refrigerated display cases, 276 ft*
2. *EC Evaporator Fan Motors in various display cases and walk-ins, 126 motors*
3. *Floating head and suction pressure control strategies on refrigeration system, 112 hp (compressor)*

Equipment Costs	Installation Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$18,129	$11,463	$29,592	$14,009	$11,582
Energy $ Savings		**Annual Return on Investment (Excluding Incentives)**		**Simple Payback**
$33,227		287% (111%)		4 months
Energy Use		**Energy Use Intensity (EUI)**		
Before	**After**	**Before**	**After**	**% Site Savings**
7,782 MMBtu/yr	6,955 MMBtu/yr	253 kBtu/ft²	226 kBtu/ft²	10.6%

Plan, Execute, Follow-up

Conduct an Energy Review

An energy upgrade project begins with an assessment of how and where energy is used in the store, and identifying and prioritizing the most cost-effective energy savings opportunities. The process requires data collection and analysis tasks known as benchmarking and energy auditing.

Benchmarking allows a performance comparison of a grocery store's baseline energy use with similar stores. This information can help store decision makers target buildings for energy audits and energy efficiency investments. Many tools and methods are available to help a supermarket identify its energy use patterns. *EPA's Portfolio Manager* is an online tool that can assess baseline energy performance in existing buildings, including grocery stores, and compile data across a system of buildings (EPA 2011a). A more detailed discussion of the benchmarking performance procedure is outlined in Section 2.4.

The benchmarking process will help identify what type of energy audit should be performed and where. The audit examines how energy is used in a facility and identifies the most cost-effective improvements. There are several types of audits, which range from a simple in-house inspection to complex data gathering and analysis conducted by a certified auditor. A comprehensive audit provides a detailed analysis of project costs and savings for all energy technology improvements available to the facility, accounts for all system interactions, and includes an implementation plan. An audit report is essential to presenting a strong business case for an energy efficiency project to store managers, owners, and other decision makers. A well-designed case will highlight the financial and educational benefits and make a competitive case for implementing the upgrades. A more detailed discussion of types of energy audits is presented in Section 2.5.

Based on results from benchmarking and energy audits, performance goals appropriate for the supermarket can be set. Goals for improving energy efficiency can be established at different levels and over varying periods, from a short-term project for an individual grocer to multiyear improvements for a supermarket chain. Many stores have established both short- and long-term goals that include quick cost savings that continue to accrue to help fund long-term improvements.

Identify Sources of Financing

A range of funding options is available for upgrade projects. Many states administer programs that provide incentives for energy efficiency improvements to supermarkets and grocery stores, while some stores have identified and secured funding resources through external sources. A comprehensive discussion of financial mechanisms is provided in Section 2.6.

Other funding sources available to the supermarket industry include leases and incentives from utility assistance programs. Many state utilities have implemented energy efficiency programs for supermarkets. For example, the New York State Energy Research and Development Authority's (NYSERDA) *Green Grocer program* is an initiative designed to help the supermarket retail industry reduce energy costs and operating costs (NYinc 2011). The program will help offset the purchase and installation costs for electric and gas efficiency upgrades, and will support innovative approaches to energy conservation, including renewable energy technologies and equipment to improve water conservation.

In addition, many federal programs provide information and assistance for improving supermarket energy efficiency. These include *EPA's ENERGY STAR for Grocery and Convenience Stores,* Natural Resources Canada's *Saving Energy Dollars in Stores, Supermarkets, and Malls*, and the U.S. Green Building Council's (USGBC) *LEED for Retail*. Another resource is the *Database of State Incentives for Renewables and Efficiency (DSIRE)*, which is a comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency.

Implement Energy Management

The shape of the implementation phase of the energy upgrade effort depends on how extensive the upgrade is. Simple EBCx measues are straightforward, but more comprehensive efforts require a methodical approach. We recommend either a staged or a whole-building approach that accounts for all system interactions in a building (integrated design), setting up an overall process to achieve the greatest energy and cost savings over the life of the project. See Section 2.3 and the EPA's *ENERGY STAR Building Upgrade Manual* (EPA 2008) for more information about project implementation.

Measure Projects and Results

Measuring performance involves gathering energy use and cost data, and analyzing the data to identify savings. These performance metrics can be compared with the baseline energy use and against established goals for energy and financial savings to determine the success of the project. This can be done by a third party to verify that the energy efficiency improvements have achieved their performance targets. This is common with an energy performance contract with an ESCO, and the ESCO must verify the promised cost and energy savings. A detailed discussion of M&V protocols is provided in Section 5.

Energy upgrades provide an initial efficiency boost, and a good O&M program will make sure that the savings persist. All building systems degrade over time—light output decreases through natural lumen depreciation and dirt buildup, and control systems drift from set points. A good O&M program anticipates all the expected degradations and monitors building status to catch the unexpected. The action items can be proactive, such as prescheduled preventative maintenance plans, and reactive, responding to problems as they arise. Details on developing an O&M plan are covered in Section 6.

Review for Continual Improvement

Once the retrofit project has been implemented, it is important to continually review the performance of the building, and identify new opportunities as they arise. Building systems that were working properly at the time of the retrofit may have degraded, new technologies may be available, and evolving customer demands may lead to remodeling efforts to improve the shopping environment. Poorly performing retrofit measures should be re-evaluated and modified if necessary. Successful projects should be recognized by corporate ownership, so the lessons learned can be applied to other stores. Individuals who contributed to the project should also be recognized.

Additional Resources

Food Marketing Institute's Sustainability Program: The Food Marketing Institute is the leading trade organization for grocery stores and supermarkets. The sustainability branch includes information, statistics, and reports about myriad EEMs. *www.fmi.org/industry-topics/sustainability*

Supermarket News: This weekly newspaper provides information about business developments in the grocery store and supermarket sector. For the reader seeking information about the latest chain consolidations, market trends, and store operator concerns, *Supermarket News* provides a comprehensive overview. *http://supermarketnews.com/*

Better Bricks: Better Bricks is an initiative of the Northwest Energy Efficiency Alliance that is devoted to helping commercial entities, including supermarkets, reap financial benefits from energy management. *www.betterbricks.com/*

Natural Resources Canada: Saving Energy Dollars in Stores, Supermarkets, and Malls: This publication of the Canadian government is a comprehensive guide to EEMs that any supermarket can undertake. *http://oee.nrcan.gc.ca/publications/commercial/16754*

ENERGY STAR for Grocery and Convenience Stores: ENERGY STAR is the preeminent consumer information source for efficient end-use appliances. The program includes resources for and case studies about supermarkets and convenience stores. *www.energystar.gov/index.cfm?c=grocery.sb_grocery*

EnergySmart Grocer Program: The EnergySmart Grocer Program provides customers with energy audits and information about efficient technology, operations, and management that illuminate the possibilities and impacts of increasing efficiency. *www.energysmartgrocer.org/*

DSIRE: DSIRE is a comprehensive source of information about state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. *www.dsireusa.org/*

DOE Retailer Energy Alliance: The Retailer Energy Alliance (REA) is one of several DOE Commercial Building Energy Alliances (CBEAs) that work with building owners, managers, and operators to share best practices and lessons learned to transform the stock of commercial buildings. The REA emphasizes proven technologies in real-world applications that achieve significant energy savings while improving bottom line profitability in the retail sector, including grocery stores. *www1.eere.energy.gov/buildings/alliances/*

2.4 Benchmarking Current Performance

Energy performance benchmarking provides baseline information that will help energy managers put together energy management plans and strategies and identify upgrade opportunities. As the benchmarking effort moves forward, it will also provide metrics to gauge program effectiveness and evaluate upgrade alternatives.

The benchmarking process compares the energy use of one or a group of stores with other stores; or looks at how energy use varies from a baseline (Table 2–1). It shows how energy is used in the building, and helps to identify the drivers of that use. As part of the benchmarking process, energy managers establish the best metrics to use for evaluating performance, select appropriate baselines to use for comparisons, and set their energy performance goals. Benchmarking can also encourage ongoing improvement if performance is periodically compared to established baselines.

Table 2–1 Common Benchmarking Baselines

Benchmark Type	Description
Best in class	The performance level of the top performers sets the bar when comparing similar buildings.
Performance goal	A specific performance level can be established as a target against which progress can be measured.
Baseline	An initial performance baseline of the building that is established before any commissioning of other measures are taken can be used to track improvements over time.
Above average	Percentages above an average can be used to establish a benchmark.
Commissioned performance level	The performance level of a commissioned building can be used as a benchmark.
National ratings	National performance ratings, such as those establisheed by ENERGY STAR, can be used as performance targets for specific buildings.

Credit: PECI

Energy managers can use the benchmarking data to determine best practices in their building portfolio and beyond, and identify the stores where those practices can be implemented. These data also help to identify top-performing stores so they can earn recognition for their efforts, and to find poorly performing stores that can be prioritized for improvement.

Benchmarking can be a complicated process, but tools are available to help. The most prominent is *Portfolio Manager*, a comprehensive, interactive online tool that is available free-of-charge through the ENERGY STAR program. The program provides a set of benchmarks developed specifically for grocery stores and supermarkets that can be used to assess energy performance. These benchmarks are developed from a national survey conducted every four years by the DOE Energy Information Administration (DOE 2006). Portfolio Manager enables users to set up private accounts to rate their buildings, set baselines, share information, and document the results of their efforts to improve energy performance.

Other software products and consulting services are available to grocery store owners as well. For example, ENERGY STAR's *Target Finder* can provide stores with specific energy goals by selecting a target EPA energy performance score or a percentage energy reduction target. LBNL offers an online benchmarking tool called *EnergyIQ*. It can compare data to peer buildings while also providing "actionable" opportunity assessments to help guide energy managers' decisions. *Oak Ridge National Laboratory* provides energy intensity charts for grocery stores and supermarkets that provide a quick comparison snapshot. *Better Bricks*, an initiative aimed at improving energy efficiency in commercial buildings managed by the Northwest Energy Efficiency Alliance, is a good resource for energy-saving ideas and case studies. PECI also offers information and programs for both smaller *grocery stores* and larger *supermarkets* to help optimize energy efficiency efforts.

Food Lion, LLC, a regional supermarket chain that operates more than 1,300 supermarkets in the Southeast and Mid-Atlantic, has used energy benchmarking for years to improve energy performance across its entire portfolio. More than 800 of its stores have earned the ENERGY STAR qualification, making Food Lion the owner of the largest number of ENERGY STAR buildings. This has led to an energy efficiency improvement of almost 30% since 2000. All these efforts have helped Food Lion win ENERGY STAR's Sustained Excellence award every year since 2004 (EPA 2011b).

Categories of Benchmarking

Energy benchmarking can be categorized as internal or external (or sometimes a combination) and as qualitative or quantitative (see Table 2–2). Internal benchmarking keeps comparisons and data within an organization's building portfolio. The data will be used to compare energy performance among the company's buildings, identifying the top performers and the best practices that can be applied to lower performing buildings within the portfolio. External benchmarking includes grocery stores and supermarkets outside the organization's control, which allows energy managers to compare the energy performance of their stores against national performance ratings. Broadening the scope in this manner helps energy managers find new energy management practices and strategies, and increases their understanding of how to evaluate energy performance. Striving to become an ENERGY STAR building would be considered external benchmarking.

Table 2–2 Four Major Categories of Benchmarking

	Internal	External
Quantitative	Compare calculated metrics of your building's performance against its own historical performance historical performance or against other buildings in your portlfolio.	Compare calculated metrics of your building's performance against similar buildings in a defined geographic area.
Qualitative	Compare management and operational practices in your building over time or against other buildings in your portfolio.	Compare management and operational practices in your building against similar buildings in a defined geographic area.

Credit – PECI

Whether internal or external, benchmarking may be either quantitative or qualitative. The quantitative approach compares numerical measures of performance, looking at how performance changes over time, or how a building's performance compares to other similar buildings. The qualitative approach analyzes management and operational practices across the entire building portfolio to identify best practices and the areas that need improvement. Benchmarking projects typically include both quantitative and qualitative measures.

Developing a Benchmarking Plan

A benchmarking plan begins with a definition of goals for the project, which helps to define the scope of the effort, identifies the metrics and the data needed, and identifies partners who may be asked to participate in the project.

1. **Set goals.** Benchmarking goals should be consistent with the overall goals for the organization. Guidelines, such as those established by the *ENERGY STAR* program, suggest evaluating energy use across the entire organization's facilities; for example, all stores within an organization's portfolio. The data can then be used to establish a baseline against which energy performance goals can be set and measured. These goals will also guide energy managers as they identify areas for improvements and target energy-saving opportunities.

2. **Define scope.** With goals defined, the scale, organizational focus, and time frame of the benchmarking effort can be addressed. The focus could be on the entire portfolio or a subset of stores, the organizational emphasis may be internal or external, and the time frame can range from weekly to annually, depending on the goals.

3. **Identify data requirements.** The data collection requirements depend on the selected benchmarking metrics and the scope of the benchmarking analysis. Table 2–3 shows some of the common energy intensity metrics used when comparing buildings. The choice of metrics depends on the goals of the benchmarking project and the type of facility. Btu per square foot is the metric most commonly used for grocery stores and supermarkets.

Table 2–3 Common Energy-Intensity Metrics

Metric	Application
Btu/ft^2	Any building
Btu/employee	Office building
Btu/unit of product	Assembly plant
Btu/lb of product	Manufacturer
Btu/lb of product processed	Refinery
Btu/number of beds occupied	Hotel or hospital
kWh/ft^2 or installed Watts/ft^2	Lighting
kW/ton	Chilled water efficiency
Watts/ft^3 of airflow/min	HVAC systems

A wide range of variables influence energy use, and they should be taken into consideration when making comparisons. For example, a 35,000-ft^2 store in Texas cannot be directly compared to a 55,000-ft^2 store in Minnesota without normalizing—accounting for the important variables such as climate conditions, hours of operation, and building size. This process enables apples-to-apples comparisons. Although this can be a complicated task, Portfolio Manager automatically normalizes energy use metrics based on key variables for grocery stores.

Tracking a benchmarking project and calculating the normalized benchmark require gathering a variety of data points. In some cases, the data, such as energy purchases and hours of operations, may already be recorded. In other cases, the data will require specific investigation or even additional measurements. Some grocery stores use energy tracking software that automatically uploads utility data to Portfolio Manager.

Common data types include energy use and cost information, physical building design, operational statistics, and climate variables. Portfolio Manager initially requires the following information for a supermarket/grocery store:

- Zip code
- Gross floor area
- Weekly operating hours
- Workers on main shift
- Presence of cooking facilities
- Number of walk-in refrigeration/freezer units
- Percent of the gross floor area that is heated
- Percent of the gross floor area that is cooled.

4. **Engage Partners.** The participation of other departments often helps the benchmarking process run more smoothly. Departments or utilities that own the data needed for benchmarking should be at the top of the list. For a grocery store chain operator, this might be the organization's corporate office, the buildings' facility managers and property owners, or the utility providers. For external benchmarking, look for other store chains with active energy management plans in place. These partners should be involved from the beginning so they understand the objectives, anticipated outcomes, and schedule. It also helps them better understand their roles and why their participation is beneficial.

   For an internal benchmarking project, it is important to be transparent and clear about what is driving the project to ensure participants do not feel threatened by the process of having their energy use and operations monitored. Emphasizing the positive effect that benchmarking can have on a grocery store's profit margin can be helpful. Annual energy costs are approximately equivalent to net profits for a typical grocery store, so reducing energy costs by 10% can also increase profits by 10% (Better Bricks 2007). Expanded awareness of the benchmarking effort helps everyone involved understand the importance of the process and the positive contribution energy efficiency has, not only on the organization's bottom line, but on the environment.

Implementing the Benchmarking Plan

Implementing the plan begins with a data collection effort, proceeds with an evaluation of benchmarking metrics, and concludes with the application of the findings. A variety of software and online tools are available to help with this process. Teams can also design custom spreadsheets to help in the analysis.

1. **Collect Data.** Participants in the data collection effort need a common platform to share the data. Portfolio Manager allows users to share information easily, but organizations can also develop their own spreadsheets and report cards. Developing unique spreadsheets enables energy managers to quickly evaluate store performance based on metrics they deem high priority. Better Bricks also offers a *tracking spreadsheet* designed for grocery stores. The spreadsheet tracks energy use and identifies trends for up to 12 stores.

Plan, Execute, Follow-up

2. **Evaluate Benchmarks and Apply the Results.** With data in hand, the project team can calculate metrics for each store under the project scope, and analyze the results. The benchmarking results can be used for a variety of purposes (Table 2–4).

Table 2–4 Applying Benchmarking Results

Purpose	Description
Rank facilities	Use data to compare or rank buildings.
Set goals	Use initial results to set new goals at either the building or organizational level.
Identify and share effective practices	Look at top performers to identify effective practices and apply to lower performing facilities.
Take action	Use the data to develop action plans across the facility portfolio, identifying sites with the most potential return.
Track progress	Use data to track progress toward organizational energy management goals and identify the organization's best practices.
Recognize achievements	Internal awards that recognize superior performance can encourage further efforts and build support for an energy management plan. External opportunities also exist through a variety of associations.

Credit – E Source

Additional Resources

Use these resources for more detailed information about benchmarking grocery store energy use.

EPA's Building Upgrade Manual: A strategic guide for planning and implementing a profitable energy-saving building upgrade following a five-stage process. Chapter 2 focuses on benchmarking. *www.energystar.gov/index.cfm?c=business.bus_upgrade_manual*

ENERGY STAR's Portfolio Manager: a comprehensive, interactive tool that provides a set of benchmarks developed specifically for grocery stores and supermarkets that can be used to assess energy performance. *www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager*

ENERGY STAR's Target Finder: A no-cost online tool that enables architects and building owners to set energy targets. *www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder*

Benchmarking Building Energy Performance: A website from Oak Ridge National Laboratory's Buildings Technology Center that includes sections about food markets. *http://eber.ed.ornl.gov/benchmark/homepage.htm*

LBNL's EnergyIQ: An action-oriented benchmarking tool for nonresidential buildings. *http://energyiq.lbl.gov/EnergyIQ/SupportPages/EIQ-about.jsp*

Better Bricks for Grocery Stores: A program, managed by NEEA, to work with supermarkets to provide unbiased advice and tools that reduce energy consumption. *www.betterbricks.com/grocery-stores*

ENERGY STAR for Retail: This program includes a section about grocery stores and supermarkets. *www.energystar.gov/index.cfm?c=retail.bus_retail*

2.5 Energy Audits

An energy audit is a systematic assessment of energy use in a building that identifies how and where energy enters the building or piece of equipment, how it is used, and areas where energy can be used more efficiently. More than 70% of energy use in stores is due to refrigeration and lighting, making these systems good targets for energy audits and upgrades. If major investments are contemplated, consider hiring a professional auditor who can provide detailed project cost and savings calculations with a high level of confidence. Outside resources, such as utility programs, are often available to help supermarkets conduct and finance audits.

There are several types of audits, which vary in the level of effort and detail required. ASHRAE (2004b) designates a preliminary analysis and three levels of energy audit, each expanding on the previous level: walk-through analysis (Level I), single system or targeted audits (Level II), and investment-grade audits (Level III). For each successive audit level both the quality and the cost of the audit increases, as shown in Figure 2–4. Only investment-grade audits account for the interactions among building systems when estimating energy savings (Table 2–5). Posing the right questions can help energy managers select the right type of audit (Table 2–6) (CEC 2000).

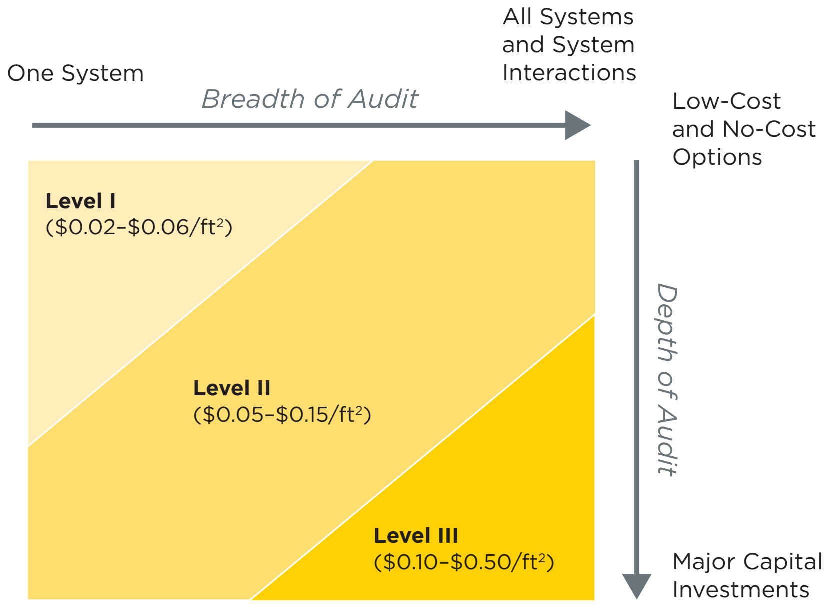


Figure 2–4 Cost and quality of the three levels of energy audits beyond preliminary analysis

Table 2–5 Types of Energy Audits

Audit Type	Accounts for Interactions?	Application Notes
Preliminary Analysis	No	Indicates overall potential for improvement
Walk-Through Analysis	No	Identifies no-cost and low-cost measures
Single System/Targeted Audits	No	Considers single systems in detail
Investment-Grade Audits	Yes	Accounts for interactions among building systems

Table 2–6 Choosing the Right Type of Audit

Question	If "yes"	If "no"
Do you want a brief analysis of the energy-savings potential in your facility?	Walk-through analysis	Targeted or investment-grade audit
Do you have an existing energy audit?	Updating existing studies	Walk-through analysis, targeted, or investment-grade audit
Have some energy efficiency projects been implemented?	Target audit focusing on specific areas not previously analyzed	Walk-through analysis, targeted, or investment-grade audit
Do you have limited funding for an audit?	Walk through analysis or targeted audit	Investment-grade audit
Do you know what projects you want to implement?	Targeted audit	Walk-through analysis or investment-grade audit
Do you want a document that will serve as an energy plan for your facility?	Investment-grade audit	Walk-through analysis or targeted audit
Are you concerned about the accuracy of predicted savings and costs?	Investment-grade audit	Targeted audit

Credit: E Source

Designating a Project Advocate

Before initiating any plans for energy audits or building upgrades, it is important to designate a project advocate who will have the time and dedication to ensure the project will receive adequate attention. This person will provide the necessary resources to an energy auditor to streamline the process and communicate the audit results to decision makers. Projects with an advocate are more likely to proceed through actual implementation of the recommendations provided by the auditor (E Source 1999). A key to the successful programs at Food Lion Inc. was the designation of an energy team and energy management plan (EPA 2011c).

Preliminary Analysis—Benchmarking

A preliminary or benchmarking analysis before the actual audit will show a store's current energy use and cost relative to similar stores, and will indicate the overall potential for improvement. Refer to Section 2.4 on benchmarking for more detail.

Walk-Through Analysis (ASHRAE Level I)

A walk-through analysis includes a study of utility bills and a visual survey of the facility. This process is simple, low cost, and usually takes less than a day. The goal is to identify low- or no-cost energy savings opportunities and estimate their potential savings. A walk-through analysis is an important component of any EBCx project, but can also be a valuable first step for more aggressive retrofit projects. The walk-through audit can highlight simple measures such as turning off lights in unoccupied areas, performing regular equipment maintenance, and checking that automatic thermostat controls are working properly. This type of audit will also help managers decide if a more detailed energy audit is worth pursuing.

Reports from a walk-through audit typically provide rough estimates of energy savings and project costs based on back of the

At each Food Lion store, utility bills and energy use are analyzed and benchmarked against other stores to identify under-performing facilities. An in-house energy field specialist then performs a walk-through audit using a utility checklist to verify that all the set points for HVAC, lighting, and refrigeration are set correctly. If determined necessary, an energy auditor performs a more comprehensive energy audit. Stores that have undergone energy audits have saved up to 12% after the walk-through (EPA 2011c).

envelope calculations. They do not take into account any interactions between systems, such as the reduced HVAC load that results from the installation of more efficient lighting. Therefore, the energy saving estimates are not necessarily accurate and should not be used in any financing decisions.

Some utility programs offer walk-through checklists for facility managers that are specific to various industry sectors. For example, Nebraska Public Power District provides an ***energy audit checklist*** specific to supermarkets that focuses on analyzing the O&M and procedures for refrigeration, lighting, HVAC, and baking equipment, which are the largest energy consumers in a grocery store (NPPD 2011).

Single System or Targeted Audits (ASHRAE Level II)

The next level up in complexity is a single system audit, which provides a more detailed building survey and energy analysis. This type of audit yields a robust analysis of one or more improvement measures. The audit may also recommend additional capital-intensive energy efficiency improvements that require more in-depth engineering analysis to estimate potential savings.

A targeted audit will identify and provide a cost and savings analysis that meets a decision maker's budget criteria. However, it does not account for system interactions and the resulting potential savings and upgrades that might be beneficial for other systems. Typically, this type of audit comes about from recommendations from a walk-through audit, or the near-term need to repair or upgrade specific pieces of equipment. Specialty equipment vendors with a focus on lighting, HVAC, thermal storage systems, or energy management systems can perform these types of audits.

Targeted audits focus on specific areas of need, and are less costly than more comprehensive audits. Because most of a grocery store's energy consumption is due to refrigeration and lighting, targeting these systems in an energy audit can be an economical way to find large potential energy saving upgrade opportunities without a comprehensive audit. However, targeted audits do not provide a management plan for future improvements, may miss non-targeted opportunities. They can be also biased, especially if the recommendations are provided by a vendor marketing the system in question.

Comprehensive Investment-Grade Audits (ASHRAE Level III)

The most comprehensive and accurate type of audit is an investment-grade audit, performed by a qualified energy auditor. It uses computer models to simulate building and equipment operations and covers the building envelope, lighting, hot water systems, and HVAC systems. Where relevant, it might include consideration of demand response, thermal energy storage, and combined heat and power opportunities.

The unique feature of an investment-grade audit is that it accounts for the interactive effects of all building systems improvements, making it an essential precedent for an integrated design strategy using either a staged or whole-building retrofit approach. An investment-grade audit allows for a rigorous total system engineering analysis that details the estimated cost and savings with a level of confidence sufficient for making financial decisions. Taking interactions into account may also lead to opportunities to reduce equipment size. For example, refrigeration system upgrades may reduce heating loads enough to downsize HVAC equipment at the end of its useful life, or earlier if it is being replaced for energy efficiency reasons. The audit produces a detailed implementation plan for energy upgrades to a facility.

An investment-grade audit provides a comprehensive analysis of project costs and savings for all potential energy technology improvements available to the facility, accounts for all system interactions, and provides a plan for implementation. However such an audit is costly and may identify more improvements than can be immediately implemented. In some cases an ESCO can create a financially beneficial project plan and help secure financing to overcome this barrier as part of a performance contract. Case Study #2 illustrates how Haggen Inc. was able to leverage a free audit to complete a very cost-effective retrofit project.

Covering the Cost of an Energy Audit

The cost of an energy audit varies with the type of audit and the complexities of a specific facility. Many state and local incentive programs offer substantial rebates or even free energy audits. Check with your local utility to learn about programs you may qualify for. Some supermarkets have incorporated comprehensive energy audits into energy performance contracts, in which the store contracts with an ESCO, which provides an energy audit as part of its design and planning services. See Section 2.6 for more about performance contracting.

Presenting Audit Results

A completed audit can be a valuable tool for making a business case for energy upgrades to decision makers—if the audit results are presented in the right way. A well-designed business case will highlight the financial and customer benefits and make a compelling case for implementing the upgrades. Decision makers will be more interested in current and historic energy costs, the benefits to customer comfort, and the effects of improvements on the operating budget and profit margin than in technical details of equipment and systems. A comparison of energy use and costs with other stores in the area, along with any local success stories, will help get the attention of decision makers. It is important to present various financing options, along with economic calculations, expressed in terms the decision makers expect. For some, simple payback will be appropriate, but for others life cycle costs and NPV will be more meaningful. Refer to Section 2.6 for more information about innovative new financing mechanisms and investment analysis.

Additional Resources

Use these resources for more detailed information on energy audits.

Energy Audit Workbook: A workbook from the Washington State University Energy Program that provides instructions, checklists, and worksheets for conducting an energy audit. *www.energy.wsu.edu/Documents/audit2.pdf*

How to Hire an Energy Auditor to Identify Energy Efficiency Projects: A report from the California Energy Commission. *www.energy.ca.gov/reports/efficiency_handbooks/400-00-001C.PDF*

Procedures for Commercial Building Audits. A report from ASHRAE that provides purchasers and providers of energy audit services with a complete definition of good procedures for an energy survey and analysis. *www.techstreet.com/cgi-bin/detail?product_id=1703613&ashrae_auth_token=*

U.S. Department of Energy, Building Energy Software Tools Directory, Whole-Building Analysis: Retrofit Analysis. This website describes a series of software tools that can aid the energy auditing and analysis process. Links to the tools—some available free of charge, some for purchase—are included. *http://apps1.eere.energy.gov/buildings/tools_directory/subjects.cfm/pagename=subjects/pagename_menu=whole_building_analysis/pagename_submenu=retrofit_analysis*

Case Study 2: Fairhaven Market Haggen

Quick Facts

- Facility Name: Fairhaven Market Haggen
- Facility type: Supermarket
- Location: Bellingham, Washington
- Gross square footage: 27,500

Credit: Haggen, Inc. Used by permission

Haggen, Inc. is an independent supermarket chain operating in western Washington and Oregon. In order to stay competitive with larger national chains, the firm has become practiced in the art of watching the bottom line.

After receiving no-cost audits through EnergySmart Grocer, an energy efficiency incentive program sponsored by its local utility, Haggen started concentrating on the cost savings available through energy efficiency retrofits.

For example, in 2009 the organization worked with several contractors to implement a diverse group of measures at one of its stores in Bellingham, Washington. The first part of the project involved replacing all the existing evaporator fan motors with electronically commutated (EC) motors. Several months later, the same contractor returned to the site to install anti-sweat heater (ASH) controllers on the site's reach-in freezer cases. The ASH controllers cycle the door heaters on and off, saving electricity directly and reducing the load on the store's refrigeration system. At the same time, a second contractor installed and programmed a new controller for the store's refrigeration system. Haggen participated in a "buying group" with several other local grocers to negotiate a lower price on the controller and installation.

"The savings at our Fairhaven store are impressive, but I am particularly happy about the impact similar projects have had across our portfolio. They are saving us more than $500,000 per year."

— Glen Foresman, VP Retail Support, Haggen, Inc.

Glen Foresman, Haggen's Vice President of Retail Support, says that he is particularly happy about the impact similar cost-effective energy efficiency retrofits have had across the Haggen portfolio. He estimates the chain is saving more than $500,000 annually from retrofits implemented over the last three years.

Key Measures

1. *Controls for Refrigerated Display Case Anti-Sweat Heaters, 160 ft*
2. *EC Evaporator Fan Motors in various display cases and walk-ins, 172 motors*
3. *Floating head and suction pressure control strategies on refrigeration system, 83 hp (compressor)*

Equipment Costs	Installation Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$20,965	$11,540	$32,505	$28,875	$3,630
Energy $ Savings		**Annual Return on Investment (Excluding Incentives)**		**Simple Payback**
$12,382		341% (38%)		3.5 months
Energy Use		**Energy Use Intensity (EUI)**		**% Site Savings**
Before	**After**	**Before**	**After**	
7,417 MMBtu/yr	6,950 MMBtu/yr	270 kBtu/ft^2	253 kBtu/ft^2	6.3%

2.6 Financing Options

Supermarket facility managers and owners face many challenges during the financial decision-making process when considering building upgrades for energy efficiency. Although the supermarket industry shares many of the energy efficiency building upgrade issues seen in other business sectors (such as lighting, heating and cooling, and appliances), its high dependence on refrigeration makes it unique. Grocers welcome energy-efficient operating cost reductions because those savings represent a competitive advantage. However, the upfront financing is critical because supermarkets operate on a thin profit margin, and few funds are available for efficiency improvements and upgrades, particularly in smaller chains and independent grocery stores.

Many large chain supermarkets lease space; small independent grocers tend to own their buildings. The duration of a lease strongly influences the payback periods of energy efficiency investments. Supermarkets that lease space generally require a 1- to 3-year payback, while independent owners are often willing to work with a 3- to 6-year payback (E Source 1998).

Many energy utilities and governmental programs have recognized the high savings potential in the supermarket industry and target it with special financing, rebates, and informational assistance to promote energy efficiency retrofits. Local energy providers may offer subsidies that can improve the estimated rate of return on energy efficiency projects, so it can be beneficial to contact the local utility to learn about local programs.

Energy upgrade projects also include nonenergy benefits—for example, making use of daylight not only cuts energy use, but can improve the shopping environment (Architectural Lighting 2008). These benefits are hard to quantify and are often omitted from a financial analysis, but should be considered when presenting an overall business case because they support a grocery store's overall mission.

The appropriate financing choice depends on many factors such as debt capacity, creditworthiness of the borrower, risk level, in-house expertise, and term of the project. Financial analysis provides insight into the most appropriate financial mechanism to fund and implement an energy efficiency project. The nature and timing of cash flows will vary by project and funding mechanism and the resulting NPV should be used to assess the benefits of the energy upgrade investment. Financing categories include capital budget, issuing of bonds, bank loans, performance contracting, and leasing.

Investment Analysis

NPV is the most accurate tool for assessing the financial worth of a building upgrade project, but financial managers often use simple payback period to justify the investment. Simple payback is defined as the number of years required for an investment's cumulative cash flow, including upfront costs, to break even. For example, a project that costs $50,000 up front but immediately results in $10,000/year of energy savings would have a simple payback of 5 years. Simple payback does not provide a measure of the long-term value of an investment, because it does not account for cash flows that occur after payback has been reached. It is also difficult to apply when retrofits are staged, because the investment occurs over multiple years and energy cost savings change over time.

NPV is a measure of investment worth that explicitly accounts for the time value of money and is used to compare the profitability of multiple financing strategies. NPV is computed from the stream of cash flows that result from the investment. Those cash flows are adjusted using a discount rate to increase the impact of upfront costs and near-term savings while reducing the values of future costs and benefits. A higher NPV indicates a more profitable investment, so when comparing project financing options, the one with the higher NPV should be chosen.

The discount rate is an interest rate used to adjust a future cash flow to its present value. As the starting point for the discount rate, most organizations begin with their cost of capital—the rate of return that must be earned to pay interest on debt from loans, bonds, leases, or other financial mechanisms. A grocery store will typically require a higher discount rate to account for risk and alternative investment opportunities. For example, suppose an organization could obtain a loan to finance the entire cost of a building upgrade with an interest rate of 5%, and requires an additional 3% return on investment. The discount rate for this project would be 8%. If the 8% discount rate results in an NPV greater than zero over the life of the project (typically 10–20 years), the project would be financially worthwhile because the cash flows would be sufficient to pay off the loan with sufficient excess cash flow to make the investment profitable.

In general, the higher the discount rate and the longer the time a cash flow will occur, the lower the NPV will be. Projects with high initial costs and savings that grow slowly over time yield lower NPVs, and projects with low initial costs and greater initial savings yield higher NPVs.

Consider two energy efficiency project options. One is a noncomprehensive retrofit project involving only lighting; the second is a more complex and comprehensive retrofit project that involves a mix of small and large EEMs. The noncomprehensive project has an initial capital cost of $100,000, which is paid off after 2.5 years and therefore has a simple payback of 2.5 years. The comprehensive project has an initial capital cost of $400,000, which is paid off after 4 years and therefore has a simple payback of 4 years. Table 2–7 illustrates the NPV calculations for both scenarios. At first glance, the simpler project appears to be the better investment because it has a shorter simple payback period. However, upon analysis using the NPV calculation, the more comprehensive project is actually the more profitable project option because it has a higher overall NPV (DOE 2008a). More detailed information about NPV analysis in the context of a grocery store retrofit project can be found in Appendix A.

Table 2–7 Comparison of NPV for Two Projects

	Project 1			Project 2		
Year	Cash Flow	Noncomprehensive Project Discount Factor (3.5% Rate)	Present Value	Cash Flow	Comprehensive Project Discount Factor (3.5% Rate)	Present Value
0	–$100,000	1.000	–$100,000	–$400,000	1.000	–$400,000
1	$40,000	0.966	$38,647	$100,000	0.966	$96,618
2	$40,000	0.902	$36,078	$100,000	0.902	$90,194
3	$40,000	0.814	$32,540	$100,000	0.814	$81,350
4	$40,000	0.709	$28,357	$100,000	0.709	$70,892
5	$40,000	0.597	$23,876	$100,000	0.597	$59,689
6	$40,000	0.486	$19,423	$100,000	0.486	$48,557
7	$40,000	0.382	$15,266	$100,000	0.382	$38,165
8	$40,000	0.290	$11,593	$100,000	0.290	$28,983
9	$40,000	0.213	$8,506	$100,000	0.213	$21,266
10	$40,000	0.151	$6,030	$100,00	0.151	$15,076
11	$40,000	0.103	$4,130	$100,000	0.103	$10,326
12	$40,000	0.068	$2,733	$100,000	0.068	$6,834
13	$40,000	0.044	$1,748	$100,000	0.044	$4,369
14	$40,000	0.027	$1,080	$100,000	0.027	$2,699
15	$40,000	0.016	$644	$100,000	0.016	$1,611
16	$40,000	0.009	$372	$100,000	0.009	$929
17	$40,000	0.005	$207	$100,000	0.005	$518
18	$40,000	0.003	$111	$100,000	0.003	$279
19	$40,000	0.001	$58	$100,000	0.001	$145
20	$40,000	0.001	$29	$100,000	0.001	$73
Total*	**$700,000**		**$131,430**	**$1,600,000**		**$178,575**

DOE 2008a

* Totals may not equal sums due to independent rounding.

Financing Mechanisms

Financing mechanisms range from more traditional forms of financing such as existing capital and in-house resources to approaches that involve third-party financing. Choosing the right financing mechanism depends on the specific needs and budget of the grocery store.

Capital budget

The simplest and most direct way to finance energy efficiency improvements is to use existing capital, or internal funds. With internal financing, projects are paid for directly with available cash drawn from a store's existing capital funds. Upfront capital investments almost always result in a short-term negative cash flow, but the resulting savings in energy use and O&M costs result in a positive cash flow in future years.

The advantages of using internal funding are that it presents a simple process for a supermarket manager that avoids complex contract negotiations or transaction delays and requires no financing costs (interest or transaction fees) paid to third parties. The supermarket retains all energy cost savings immediately, which decreases operating expenses in future years.

The most significant disadvantage of using internal funds is that most grocery stores work on thin margins and do not have the upfront capital. Even if a project can show an impressive return on investment and NPV, it may be inhibited by lack of capital. In-house expertise on energy audits, project design, cost estimation, and project management are required, and the building owner assumes all risks associated with the investment. And for leased stores, the payback period may be longer than the term of the lease.

Revolving investment

Certain large-chain grocery stores may use revolving investment funds, which involve investing capital in energy efficiency projects, with some or all of the savings from avoided energy costs used as repayment to the revolving fund. Excess savings allow the fund to grow and be reinvested in additional phases of energy efficiency improvements. However, revolving funds require upfront capital and a relatively long period of time to realize the full savings of energy upgrades, both of which may be unattractive to supermarket owners.

Bank loan

The private sector often uses bank loans to finance traditional energy efficiency improvements such as equipment upgrades, and may a good option when upgrading supermarket refrigeration equipment. Bank loans are often used to finance small, shorter term energy efficiency improvements, usually within the private sector.

There are several benefits to using a traditional loan. The payments are fixed and structured to be less than the anticipated energy savings, resulting in positive cash flow, and the depreciation and interest are tax deductible. The cost savings of the upgrades are realized immediately, and you own the equipment from the start. Loans are a simple mechanism to fund smaller projects and are quick to obtain.

Loans typically require a substantial down payment, making them less attractive for supermarkets that need these funds for operational expenses and other priorities. Lenders also usually do not cover the "soft costs" of a project, such as consulting and installation fees. Therefore, for larger and more comprehensive energy upgrades, supermarkets may consider leases, bonds, and performance contracts, discussed in later sections.

Bond issue

Bonds, which are sold by public and private sector organizations to borrow money from capital markets, are the second form of traditional debt financing and are generally used to fund large projects. Tax-exempt bonds are issued by a state or local government development agency on behalf of a private business. The interest income earned by the lender is exempt from state and local taxes, and is passed to the borrower through lower interest rates.

In general, the greatest advantage of utilizing bonds to finance large projects is that they usually have a low, tax-exempt interest rate compared to other financing options. They also avoid relying on precious internal capital and operating budgets, and the financing costs can be structured to be repaid from the positive cash flow from energy savings.

However, bonds are complex agreements that often require input from attorneys, accountants, and investment bankers. This adds administrative costs and fees to the original financing cost. Bonds incur a debt that is reflected on the balance sheet, and issuing bonds can require a lengthy approval process.

Energy savings performance contract

Though not a financing mechanism, performance contracting can help identify and facilitate appropriate financing for large-scale energy efficient building upgrades in both the private and public sectors. An energy savings performance contract is an agreement with a private ESCO to deliver a group of efficiency measures with no capital investment by the building owner. The ESCO develops, installs, assists in arranging financing, and manages the project from start to finish. The energy and other operational savings generated by the upgrades are used to repay the entire cost of the project. A performance contract provides the opportunity for an organization to implement comprehensive energy efficient building upgrades that otherwise would not have been possible because of limited capital or debt capacity.

Performance contracting allows the implementation of multiple comprehensive energy efficiency improvements that result in the greatest energy savings, with no upfront costs to the store owner. An ESCO serves as a single point of accountability, and offers the expertise to implement high-quality projects and the experience to guarantee savings. Typically, the payments are funded through the realized energy savings, so that there remains a level cash flow.
In general, performance contracts are a good solution for grocery store managers that lack the necessary technical expertise, are budget constrained and need their resources for other priorities, and do not have the time or experience to manage complex improvement projects. For most grocery stores, the economics favor financing over waiting for internal funds to become available.

The main disadvantage of performance contracting is that a significant portion of the savings generated by the project are paid to the ESCO, making the project cost more than if it were performed in house, but likely no more than would be paid to a contractor for the same work. The negotiations and planning can be lengthy and complex, and the contracts tend to be long term, ranging from 5 to 10 years.

The combination of refrigeration and lighting retrofits with the addition of an advanced building management system can be an excellent retrofit bundle for a supermarket performance contract. In addition, including ongoing maintenance in a performance contract can help to keep O&M costs under control and predictable. This is particularly relevant for grocery store owners who would normally outsource system maintenance, because performance objectives would be built into the contract. Having a long-term contract in place should also provide an impetus for long-term strategic planning of equipment upkeep and replacement (EPA 2008).

Lease purchase

A lease is basically a loan in which the lender retains legal title to the property. Leases tend to be quick and easy to implement compared to other forms of financing and can have short terms relevant to the supermarket industry. Grocery store managers often use either operating or capital leases to finance equipment upgrades and replacements.

Operating leases. In an operating lease, the lessee rents equipment from the lender for a fixed monthly fee. At the end of the lease, the lessee may purchase the equipment for fair market value, extend the lease, or return the equipment. Operating leases are simple because they can be funded through operating budgets, and are a good choice for short-term projects. The payments tend to be smaller than for capital leases and are tax deductible, whereas with a capital lease, only the interest on the payment is deductible.

Capital leases. Under a capital lease, the lender owns the equipment until the end of the lease term, when the title will then pass automatically to the lessee for a small fee. These types of leased assets are depreciated, so the depreciation and interest portions of the lease payment are tax deductible. There are advantages to capital leases over a traditional bank loan because they do not fall under the same strict obligations as banks. They require little or no down payment, involve little paperwork, and are approved much quicker. They can be used to finance soft costs that are hard to fund through a bank loan. More than 100% of the value of equipment can be leased and the excess used to fund the soft costs.

On-bill financing

On-bill financing through local utilities is another way to fund energy efficiency improvements without heavy upfront capital spending. It is applicable to small to medium projects in the private and public sectors. A utility, or other third-party financial institution, incurs the upfront costs of improvements and recoups the investment by incorporating loan repayment into future energy bills. This approach eliminates upfront costs, and the repayment schedule is structured so that the energy savings are greater than the payment. On-bill repayment is simple to initiate as utilities already have established billing and access to information about a store's energy usage patterns and payment history. However, utilities are often reluctant to take on the role of financing, and agreements can be complex to set up. Grocery store energy managers can contact their local utility to learn if on-bill financing or other programs are available in their area.

Additional Resources

Use these resources for more detailed information on financing options for grocery and supermarket energy efficiency upgrades.

ENERGY STAR Cash Flow Opportunity Calculator: A spreadsheet designed to help decision makers quantify the costs of delaying an energy efficiency project. *www.energystar.gov/index.cfm?c=business.bus_financing*

ENERGY STAR Building Upgrade Manual: A strategic guide for planning and implementing a profitable energy saving building upgrade following a five-stage process. Chapters 3 and 4 focus on investment analysis and financing. *www.energystar.gov/index.cfm?c=business.bus_upgrade_manual*

Easy Access to Energy Improvement Funds in the Public Sector, Government Finance Review: An article that shows how the money saved from increased energy efficiency can be used to finance efficient equipment. *www.energystar.gov/ia/business/government/Financial_Energy_Efficiency_Projects.pdf*

Energy Savings Performance Contracts: This web page from the Federal Energy Management Program (FEMP) provides guidance on energy performance contracts. *www1.eere.energy.gov/femp/financing/espcs.html*

Energy Services Coalition: This group provides resources for energy performance contracting. *www.energyservicescoalition.org*

National Association of Energy Service Companies: NAESCO provides background information and helps users and providers of energy service contracts. *www.naesco.org*

eValuator: This financial analysis software can be downloaded for free from the Energy Design Resources website. It calculates life cycle benefits of improved building design investments and provides financial information necessary for making sound building upgrade decisions. *www.energydesignresources.com/resources/software-tools/evaluator.aspx*

Supermarket Programs: A discussion of supermarket efficiency programs and performance contracts from PECI. *www.peci.org/commercial-retail/supermarket/index.html*

Better Bricks: A program to encourage energy efficiency in the Northwest. The website includes a supermarket section. *www.betterbricks.com/grocery-stores*

Small Business Association Energy Efficiency for Grocery and Convenience Stores: A webpage dedicated to improving the energy efficiency of commercial refrigeration systems. *www.sba.gov/content/energy-efficiency-grocery-and-convenience-stores*

3 Existing Building Commissioning

Significant energy savings can often be achieved in grocery stores with minimal risk and capital outlay by improving building operations and restructuring maintenance procedures. This process, commonly known as existing building commissioning, or EBCx, tunes up building performance. EBCx can take the form of retrocommissioning (RCx) when performed for the first time in an existing building, or recommissioning when it is performed as a follow-up to the original commissioning process. Besides being a highly cost-effective strategy (see sidebar in Section 1) for reducing energy use, EBCx can help reduce O&M costs and ensure the persistence of proper operation. It is typically a good first step on the road to increased energy performance, whether using a staged or integrated approach.

An EBCx process usually consists of four phases: planning, investigation, implementation, and hand-off. The EPA's *"A Retrocommissioning Guide for Building Owners"* includes a detailed discussion of the activities that take place in each of these phases (PECI 2007b). The EBCx process may vary slightly for specific projects, but most projects follow the process shown in Figure 3–1.

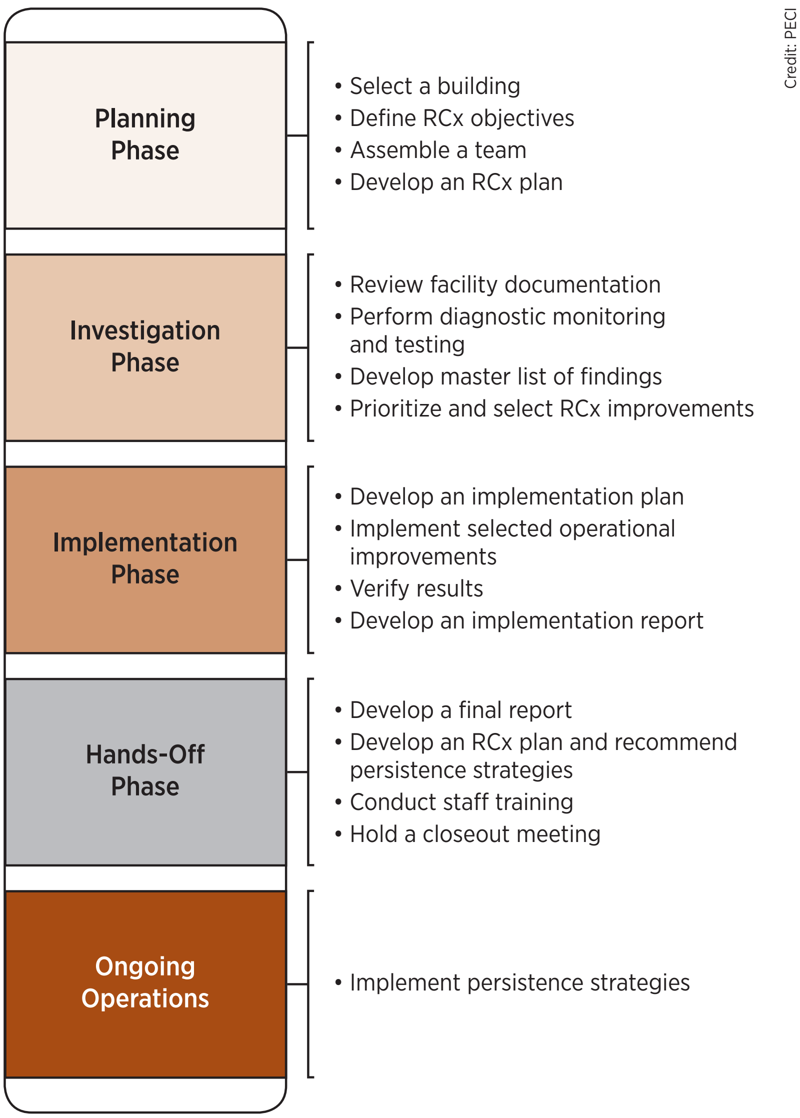


Figure 3–1 Phases of an effective EBCx project

Much of the effort and cost of EBCx are applied during the investigation phase. An outside EBCx provider, or perhaps an experienced energy manager for larger grocery store chains, works with the facility manager to conduct an in-depth investigation into building operations. This provides a detailed understanding of the systems and assemblies and identifies operational improvements. About half the overall project cost is usually devoted to the EBCx provider's work on the project, which includes this in-depth investigation. The other half is devoted to implementing the measures. Further considerations for cost and the choice of an EBCx provider are presented in Section 3.3.

EBCx is generally recommended even when retrofits are being considered, to optimize building system operations before the retrofits are designed and implemented. This approach also enables savings to accrue even while planning proceeds for more comprehensive upgrades. However, if a facility has scheduled retrofits in the near future, it may make sense to delay implementation of some EBCx measures until those retrofits have occurred. Aside from being a highly cost-effective strategy for reducing energy use, EBCx can help reduce other costs besides energy, and help ensure the persistence of proper operation. It provides a good first step on the road to increased energy performance, whether using a staged or integrated approach. This potential for a very quick payback, especially when an energy management system is present, is illustrated in Case Study #3.

This section begins with an EBCx Measure Summary Table that provides a list of the highest priority measures that should be considered as part of an EBCx project. The measures included in this list were identified by evaluating the most common and cost-effective measure options being implemented in grocery stores. More detailed information about the application of each EBCx measure to grocery stores is provided in Appendix E, which presents a brief technical overview, addresses strengths and weaknesses, and discusses special considerations related to building vintage, size, and climate. It also presents a second tier of EBCx measures that may be worth exploring, depending on the current state of the store.

This section continues with a set of recommended packages of EBCx measures that were selected based on their appropriateness for the example grocery store in each climate region. Details of the approach used for cost-effectiveness analysis are provided in Section 1.4 and Appendix A. Our analysis indicates that implementing the recommended packages can produce a large positive NPV and payback periods of less than 2 years in all regions of the country.

This section concludes with considerations for the EBCx process that address factors that can influence cost effectiveness, and aspects to consider when evaluating measures. Because all buildings are unique and have particular needs and opportunities for energy upgrades, building owners are encouraged to think about how these aspects will influence their projects.

Case Study 3: Jewel-Osco Supermarket Retro-Commissioning

Quick Facts

- Facility Name: Jewel-Osco
- Owner: SUPERVALU, Inc.
- Location: Palos Heights, Illinois
- Gross square footage: 61,159 ft^2
- Energy Use Intensity: 220.41 $kBtu/ft^2$

The Jewel-Osco store in Palos Heights, Illinois, was retro-commissioned in 2010 as part of SUPERVALU's strategy to update older facilities with improved control systems, with the goal of reducing energy consumption. The process started with the installation of an energy management system (EMS) for HVAC and lighting controls. This step gave staff more precise control over the HVAC system and enabled energy-saving strategies such as night setbacks for temperatures and lighting.

"SUPERVALU aggressively pursues opportunities to save energy and improve our operations. We have found enhancing existing controls in some older facilities is a great opportunity to reduce our consumption. We are able to apply many of the lessons learned from our participation in the Commercial Building Energy Alliance in our retrofit strategy. "

— Dustin Lilya, SUPERVALU
Manager, Technology Development & Integration

Credit: Diane Laux/Patch.com, used by permission

The commissioning project also targeted the refrigeration system with the installation of floating head controls on 40 single compressors, and anti-sweat heater controls on refrigerated cases.

The project saved nearly 300,000 kWh in the first year, resulting in a simple payback of 1.06 years.

Key Measures

1. *Installed environmental control panel for HVAC and lighting control*
2. *Implemented floating head control for 40 single compressors*
3. *Improved cycling strategy for four air-cooled condensers*
4. *Installed additional zone temperature sensors for finer control of main air handling unit*
5. *Installed time-of-day controls for lighting*

Energy $ Savings		Total Costs		Simple Payback (years)
$23,740/yr		$24,928		1.06
Energy Use		**Energy Use Intensity (EUI)**		
Before	**After**	**Before**	**After**	**% Site Savings**
14,490 MMBtu/yr	13,480 MMBtu/yr	237 $kBtu/ft^2$	220 $kBtu/ft^2$	7%

3.1 EBCx Measure Summary Table

A total of 38 EBCx measures suitable for grocery stores are presented in this section, and described in more detail in Appendix E. These measures were carefully selected by retrofit experts based on the likelihood that they will yield significant energy savings in typical store at little or no cost. A summary of these measures and their applicability to each climate region is provided in Table 3–1. Note that most EBCx measures are worthwhile in all climates because of the low cost of implementation.

Table 3–1 EBCx Measure Summary Table

System	Measure Description	Applicable to:					Stage (see Section 2.2)	Section
		Miami	Las Vegas	Seattle	Chicago	Duluth		
Lighting	Calibrate any existing lighting controls and optimize settings based on building usage patterns and daylight availability	✓	✓	✓	✓	✓	1	E.1.1
	For fixtures with one or more burned-out lamps, replace all lamps with lower wattage versions that produce equivalent or superior light output and quality	✓	✓	✓	✓	✓	1	E.1.2
	Adjust light levels to within 10% of the Illuminating Engineering Society recommendations for the tasks conducted in each area by delamping and/or relamping	✓	✓	✓	✓	✓	1	E.1.3
	Improve janitorial workflow to consolidate activities in each area, allowing a reduction in operating hours for lighting	✓	✓	✓	✓	✓	1	E.1.4
Plug & Process Loads	Control computer power management settings facility wide through software or logon scripts, ensuring settings cannot be overridden	✓	✓	✓	✓	✓	1	E.2.1
	Use timers for compressors and turn off lights on vending machines	✓	✓	✓	✓	✓	1	E.2.2
	Provide power strips in easy-to-access locations to facilitate equipment shutdown	✓	✓	✓	✓	✓	1	E.2.3
	Apply standby mode to registers when not in use; turn registers off when store is closed	✓	✓	✓	✓	✓	1	E.2.4
	Obtain lower electricity rates (where available) by allowing the utility to disable nonessential equipment during peak load periods or by participating in a demand response program	✓	✓	✓	✓	✓	1	E.2.5
	Schedule cooking activities to use equipment at full capacity	✓	✓	✓	✓	✓	1	E.2.6
	Verify that airflow paths around transformers are not blocked	✓	✓	✓	✓	✓	1	E.2.7
	Verify balanced 3-phase power and proper voltage levels	✓	✓	✓	✓	✓	1	E.2.8

Table 3–1 EBCx Measure Summary Tab (cont'd.)

System	Measure Description	Applicable to: Miami	Las Vegas	Seattle	Chicago	Duluth	Stage (see Section 2.2)	Section
Refrigeration	Ensure that open refrigerated cases are covered when store is closed	✓	✓	✓	✓	✓	1	E.3.1
	Raise set points in refrigerated cases when possible	✓	✓	✓	✓	✓	1	E.3.2
	Clean and calibrate humidity sensors that control anti-sweat heaters	✓	✓	✓	✓	✓	1	E.3.3
	Repair or replace gaskets and seals on refrigerated cases	✓	✓	✓	✓	✓	1	E.3.4
	Verify correct charge in refrigeration systems, and repair any refrigerant leaks	✓	✓	✓	✓	✓	1	E.3.5
	Verify optimal head and suction pressures	✓	✓	✓	✓	✓	1	E.3.6
	Verify or establish an effective maintenance protocol for the refrigeration system, and for cooking equipment in kitchen areas and break rooms, including cleaning evaporator and condenser coils, exhaust vents, and burners	✓	✓	✓	✓	✓	1	E.3.7
	Ensure that airflows in refrigerated cases are not blocked by improperly stocked shelves	✓	✓	✓	✓	✓	1	E.3.8
Envelope	Weatherstrip or caulk windows and doors where drafts can be felt	✓	✓	✓	✓	✓	1	E.4.1
Service hot water	Reduce set point for domestic hot water to 120°F, with boost heating for dishwashers and other cleaning or sanitizing operations	✓	✓	✓	✓	✓	1	E.5.1
	Install low-flow aerators on faucets	✓	✓	✓	✓	✓	1	E.5.2
	Disable circulation pumps when building is unoccupied	✓	✓	✓	✓	✓	1	E.5.3

Table 3–1 EBCx Measure Summary Tab (cont'd.)

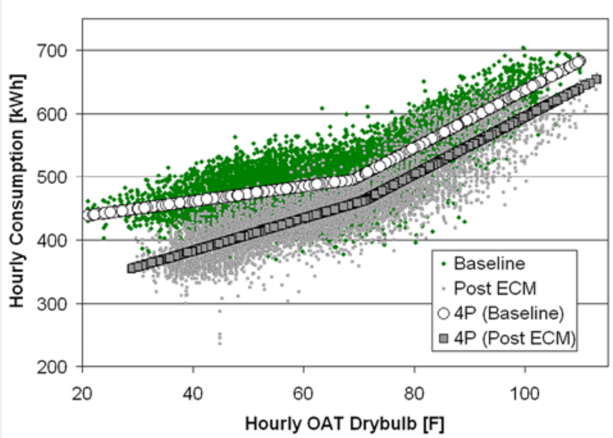
System	Measure Description	Applicable to: Miami	Las Vegas	Seattle	Chicago	Duluth	Stage (see Section 2.2)	Section
HVAC: Heating & Cooling	TAB valves and refrigerant lines to ensure that supply air temperatures (SATs) meet cooling loads and no unnecessary flow restrictions are present	✓	✓	✓	✓	✓	1	E.6.1
	Verify or establish a comprehensive maintenance protocol for HVAC equipment, including cleaning cooling and heating coils, burners, and radiators	✓	✓	✓	✓	✓	1	E.6.2
	Clean or replace air, water, and lubricant filters	✓	✓	✓	✓	✓	1	E.6.3
	Verify correct operation of outside air (OA) economizer	✓	✓	✓			1	E.6.4
	Ensure correct refrigerant charge in cooling systems and heat pumps, and repair any refrigerant leaks	✓	✓	✓	✓		1	E.6.5
	Increase thermostat setback/setup when building is unoccupied	✓	✓	✓	✓		1	E.6.6
	Re-optimize SAT reset based on current building loads and use patterns	✓	✓	✓	✓	✓	1	E.6.7
	Verify adequate deadband between heating and cooling	✓	✓	✓	✓	✓	1	E.6.8
	Move improperly located thermostats to prevent over- or under-cooling/heating	✓	✓	✓	✓	✓	1	E.6.9
	TAB air handlers and flow modulation devices to ensure that conditioned air volumes meet load requirements	✓	✓	✓	✓	✓	1	E.6.10
	Update and maintain a systems manual with O&M requirements	✓	✓	✓	✓	✓	1	E.6.11
HVAC: Ventilation	Suspend ventilation during unoccupied periods	✓	✓	✓	✓	✓	1	F.7.1
	Test and adjust ventilation flow rates as needed to meet ASHRAE 62.1 requirements	✓	✓	✓	✓	✓	1	F.7.2

Many of the measures listed in Table 3–1 were applied in the comprehensive RCx project described in Case Study #4.

Case Study 4: Northern California Supermarket Retrocommissioning

Quick Facts

- Facility type: Supermarket
- Climate zone: ASHRAE Zone 3B
- Year Built: 1997
- Gross square footage: 65,000



A large supermarket in northern California completed a project combining retrocommissioning and some limited retrofit measures during the last three months of 2007.

As with many retrocommissioning projects, the list of implemented measures was extensive and included both small control adjustments and more extensive equipment repairs and replacement.

Lighting measures included adding and updating schedules to the sales floor, refrigerated display case, and exterior lighting.

The site's built-up HVAC system saw a deeper level of commissioning, including the implementation of a night setback set point and the addition of a variable speed drive (VSD) on the supply air fan. Additionally the economizer, which was found on inspection to be inoperative, was repaired and its control sequence was commissioned.

The refrigeration system, as the site's most complex and energy-intensive system, received the most attention and effort. The controls system was updated to allow more complex control strategies to be implemented, such as floating head pressure. The defrost schedules were also sequenced to occur nonconcurrently and at nonpeak hours to reduce peak demand charges. The control sequences for the air-cooled condensers were updated to correctly stage the fans on and off and to shut two of five condensers off during the winter months when the additional capacity was unnecessary.

Even with the high costs involved for the extensive commissioning process described above, the energy savings achieved a positive cash flow after just 6 months.

Key Measures

1. *Implement night setback and repair economizer control on built-up HVAC unit*
2. *Adjust control sequence for refrigeration condensers*
3. *Reprogram schedules for sales floor, refrigerated display case, and exterior lighting*

Equipment Costs	Installation Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$14,249	$33,217	$47,466	$16,879	$30,587
Energy $ Savings		**Annual Return on Investment (Excluding Incentives)**		**Simple Payback**
$61,617/yr		201% (130%)		6 months
Energy Use Before	**Energy Use After**	**Energy Use Intensity (EUI) Before**	**Energy Use Intensity (EUI) After**	**% Site Savings**
15,549 MMBtu/yr	13,932 MMBtu/yr	239 kBtu/ft^2	214 kBtu/ft^2	10.4%

3.2 Recommended Packages

At-a-Glance Results

A summary of the EBCx measures selected for the example grocery store is presented in Table 3–2. Eight of the measures from Section 3.1 that were deemed to be the largest energy savers and that could be applied to the example building have been recommended as an example package, but as discussed in Section 3.3, other measures may also be cost effective depending on the site specifics. Certain measures are not in the package because the example building does not have relevant equipment or envelope characteristics. For example, calibration of lighting controls is not included because the example building does not have automatic lighting controls, though we assume it does have a basic EMS. See Section 1.4 for an explanation of the EEM selection process for EBCx projects, and Appendix B (Section B–3) for further information about the example building.

Table 3–2 EBCx Recommended Packages—Results of Common Metrics

Location	EUI (kBtu/ft²)*			Energy Cost/ft²*		
	Baseline	Post-EBCx	% Reduction From Baseline	Baseline	Post-EBCx	% Reduction From Baseline
Miami (Hot & Humid)	203	184	9%	$4.54	$4.20	8%
Las Vegas (Hot & Dry)	219	189	14%	$4.67	$4.09	13%
Seattle (Marine)	238	198	17%	$4.97	$4.27	14%
Chicago (Cold)	265	226	15%	$5.86	$5.04	14%
Duluth (Very Cold)	301	254	15%	$5.70	$4.84	15%
Average	245	210	14%	$5.15	$4.49	13%

*Annual cost and energy savings are first year values. Cost savings are expressed in 2011 dollars, and include the effect of annual M&V costs.

The measures included in the EBCx packages are shown in Table 3–3.

Table 3–3 EBCx Measures in Recommended Package

System	Measure Description	Climate Zone	Section
Refrigeration	Raise set points in refrigerated cases when possible	All	E.3.2
Refrigeration	Clean and calibrate humidity sensors that control ASHs	All	E.3.3
Refrigeration	Verify correct charge in refrigeration systems, and repair any refrigerant leaks	All	E.3.5
Refrigeration	Verify optimal head and suction pressures	All	E.3.6
HVAC	Verify correct operation of OA economizer	All	E.6.4
HVAC	Increase thermostat setback/setup when building is unoccupied	All	E.6.6
HVAC	TAB air handlers and flow modulation devices to ensure that conditioned air volumes meet load requirements	All	E.6.10
HVAC	Suspend ventilation during unoccupied periods	All	E.7.1

Rationale for Recommended Measures

The measures in the EBCx package were chosen based on their frequency of occurrence on EBCx projects, ease of implementation in the example building, and likelihood of implementation. Further discussion of the process for developing recommended packages can be found in Section 1.4.

Note that the measures included in the recommended package are only a subset of the measures listed in the EBCx Measure Summary Table in Section 3.1. An EBCx process typically identifies many opportunities for improved O&M and energy performance. Often, some of those opportunities are not implemented, for reasons such as budgeting, scheduling, and planned work that would affect the measure. In addition, the auditing process may indicate that some measures are unnecessary because O&M are already adequate. The measures in the EBCx package were chosen as a representative mix of measures that could be implemented as part of an EBCx process.

Energy Savings

The detailed energy and demand savings for the recommended EBCx packages are shown in Table 3–4. These values were determined by applying the measures to the grocery store reference building described in Appendix B.

Table 3–4 EBCx Recommended Package Energy Savings Results

Location	Electricity Savings (annual kWh)	Electric Demand Savings (peak kW)	Gas Savings (annual therms)	Site EUI Savings (kBtu/ft²)	Savings as % of Total Site Use	Source EUI Savings (kBtu/ft²)	Savings as % of Total Source Use
Miami (Hot & Humid)	237,424	16	380	19	9%	61	9%
Las Vegas (Hot & Dry)	323,430	26	2,366	30	14%	83	14%
Seattle (Marine)	362,872	26	5,512	40	17%	94	17%
Chicago (Cold)	346,852	27	5,896	39	15%	89	15%
Duluth (Very Cold)	357,925	26	8,735	47	15%	92	15%

As shown, EBCx measures can yield significant energy savings. The overall reductions in building energy use shown in the table are based on actual EBCx projects across a range of building types, and may not be representative for grocery stores (Mills 2009). The site-to-source conversion factors for electricity and gas are calculated using a nationwide average based on an NREL study of transmission and distribution losses (Deru and Torcellini 2007).

Financial Analysis

The cost of individual measures can vary greatly, depending on the baseline condition of the store and the work involved in implementing the measures. Studies have shown that the average cost for an EBCx project, including commissioning and minor repairs, is $0.30/ft^2 (Mills 2009). Applying this value to the example grocery store and applying inflation rates for the past 2 years gives an overall EBCx package cost of $0.31/ft^2 (see Table 3–5).

Table 3–5 EBCx Recommended Package Financial Analysis Results

Location	Total Measure Costs	Total Energy Cost Savings	Simple Payback (Years)	NPV
Miami (Hot & Humid)	$13,754	$15,431	0.9	$60,741
Las Vegas (Hot & Dry)	$13,754	$26,299	0.5	$113,592
Seattle (Marine)	$13,754	$31,798	0.5	$140,868
Chicago (Cold)	$13,754	$36,583	0.4	$163,857
Duluth (Very Cold)	$13,754	$38,494	0.4	$173,444

As shown, EBCx has a fast simple payback and positive NPV, making it an attractive method to achieve energy savings. The LBNL commissioning study has shown that EBCx has a simple payback of 1.1 years, on average, based on energy savings (Mills 2009).

Nonenergy benefits, such as improved thermal comfort and extended equipment life, can also be achieved by the EBCx process. The estimated median nonenergy impact of EBCx across a variety of building types is about $0.18/ft^2. This is significant, when compared to the median energy savings of $0.29/ft^2 related to EBCx (Mills 2009). For grocery stores specifically, these values may be higher or lower, because the nature of typical grocery store equipment and HVAC systems are not necessarily representative of all commercial buildings. Although savings may be realized beyond the energy savings reported in Table 3–5, some costs may also increase. For example, energy use will increase in some stores that were operating with insufficient refrigerant levels or stores that were not providing code-mandated product temperatures. Additional O&M expenses may be required to maintain optimal energy performance after the EBCx process. For this analysis, the additional nonenergy costs and benefits were assumed to cancel out.

To maintain the energy benefits related to EBCx measures, the performance of the related equipment and systems must be maintained through periodic monitoring. The financial analysis assumes that the measure life of EBCx is 5 years, with ongoing maintenance of the improvements. Full recommissioning should be performed every few years to maintain the persistence of benefits over a longer time horizon. The cost of recommissioning is usually less than the cost of initial EBCx.

The EBCx measures proposed in the recommended packages above and comprehensive EBCx measure discussions in Appendix E provide a starting point for measure options to be considered for most grocery stores. However, not all measures will be applicable to all buildings, because all buildings are unique. Other measures not included in the preceding discussion may be applicable to a specific building. Some are listed at the end of Appendix E. The EBCx process, which includes an in-depth investigation into building operations, identifies opportunities for improved performance, including energy performance, occupant comfort, O&M, and equipment performance. The extent of the opportunities identified will be partly dependent on the comprehensiveness of the EBCx scope.

Building owners considering implementing the EBCx process will benefit from consulting the detailed measure descriptions in Appendix E to gain an understanding of the types of measures typically implemented as part of an EBCx project. This Appendix includes a discussion of each measure's technical characteristics, special considerations, and technical assumptions for implementing the measure in the context of a typical grocery store.

3.3 Additional Considerations

An experienced EBCx provider can help determine if a building is a good candidate for EBCx. In addition, an ASHRAE Level I energy audit can help determine a building's suitability for EBCx and give greater confidence in proceeding with an EBCx project. Some indicators of a store that is a good candidate for EBCx include (EPA 2007):

- High, unjustified energy use
- Low-performing building equipment or control systems
- High equipment failure rates
- The presence of electronic controls, or an EMS, which make it easier to implement many of the measures
- Experienced and available in-house staff
- Up-to-date building documentation.

Employees and customers can also signal the need for EBCx. A building with a high number of occupant complaints is often a good candidate for EBCx. In such a building, the measures that will result from an EBCx project will achieve energy savings and may help to retain customers. The building commissioning industry suggests that it is good practice to engage building occupants during investigation and persistence phases of commissioning (Building Commissioning Association 2008).

When evaluating EBCx measures to apply in a specific building, the following questions should be considered to help narrow the options to a manageable number:

- *Is the measure applicable to the systems and assemblies in the building?* Certain measures may not be feasible due to the constraints of the installed systems. For example, adding equipment lockouts based on outside air temperature may not be feasible for some types of HVAC systems.
- *Is the measure relevant to the operations of the building?* Measures that affect indoor air quality (IAQ) should be closely evaluated and considered, as they may impact occupant health and comfort. Also, the capabilities of the service contractors and operations staff should be considered when evaluating measures. Do the contractors and staff have the necessary skills and knowledge to support the measure? If not, is there additional training that they can receive?
- *How difficult will it be to ensure that the measure persists?* After measures are implemented, they require periodic monitoring to ensure that the benefits of the measures are realized over time. Sufficient resources and strategies must be put into place to ensure measure persistence.
- *Are there planned retrofits that may nullify the benefits of the EBCx measure?* If a facility has scheduled retrofits in the near future, it may make sense to delay implementation of EBCx measures until those retrofits have occurred. For example, if the exterior lighting will soon be upgraded to more efficient fixtures, it may not be worth calibrating the lighting controls before the retrofit.

The cost of EBCx is an important consideration for most store owners. Much of the cost of EBCx relates to the provider cost—for the planning, investigation, and hand-off phases of a typical project (Mills 2009). And most of the provider cost is spent during the in-depth investigation portion of the project. Although the cost of implementing EBCx measures is typically low, it is important to also consider this provider effort, which is necessary to identify the best opportunities. In-house staff or service contractors may be used, but EBCx providers are typically better suited for managing the process for the following reasons:

- The in-house staff or service contractors may not have the resources to lead the process, or the skills to perform the in-depth investigation.
- A third-party EBCx provider offers a "second set of eyes," with significant experience to draw upon and without biased notions about how the building should perform.
- EBCx providers have the specialized tools for performing the work—e.g., data loggers, functional test forms, and power monitors
- EBCx providers have the necessary analytic skills and resources for diagnosing performance issues and determining the cost effectiveness of identified improvements.

3.4 Additional Resources

Use these resources for more detailed information on EBCx strategies for grocery stores and supermarkets.

Advanced Variable Air Volume System Design Guide from the California Energy Commission provides general guidelines for optimizing systems (CEC 2005a) *http://uccsuiouee.org/seminars/UC%20CSU%20VAV%20Design%20Guide.pdf*

Functional Performance Test, Air-Side Economizer: PECI provides this free checklist for economizers. *www.peci.org/ftguide/ftg/SystemModules/AirHandlers/AHU_ReferenceGuide/CxTestProtocolLib/Documents/econtest.doc*

General Commissioning Procedure for Economizers: Pacific Gas & Electric developed these guidelines for commissioning economizers. *www.peci.org/ftguide/ftg/SystemModules/AirHandlers/AHU_ReferenceGuide/CxTestProtocolLib/Documents/EconomizerProcedure.doc*

Assessing Economizer Performance: An application note from Pacific Gas & Electric's Pacific Energy Center providing guidance on how to identify problem areas for economizers. *www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/tll/appnotes/assessing_economizer_performance.pdf*

EPA, "A Retrocommissioning Guide for Building Owners," 2007: A comprehensive guide to the EBCx process. Also includes case studies, sections on lease structures and impacts to building financial metrics. Available for free download online. *www.peci.org/documents/EPAguide.pdf*

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4 Building Retrofits

Building retrofit measures include equipment, system, and assembly enhancements or replacements. This section provides guidance for selecting the right package of retrofits, proven practices for implementing those measures in a grocery store, and case studies that apply the measures in real-world situations.

4.1 Whole-Building Approach

A whole-building approach to energy efficiency upgrades focuses on the retrofits of multiple building systems, with a package of measures of varying financial benefits being installed at the same time. For example, an energy manager may complete a lighting system retrofit at the same time roof insulation and the HVAC system are improved.

The whole-building approach is well suited to energy managers who either have ambitious energy savings goals to be met in a short period of time, or have the opportunity to install more comprehensive retrofit measures because of planned changes in a building's systems, such as those that occur when a building is repurposed or undergoes a major renovation. From a financial perspective, implementing multiple measures simultaneously has two distinct benefits:

- The overall economics of the project are often improved. Cumulative project costs can be reduced compared to the staged approach, due to efficiencies from installing multiple measures at once. Life cycle benefits may be simultaneously increased, as energy savings begin at a high level, rather than phasing in over time as stages are completed.
- The whole-building approach allows for optimization of equipment sizes when multiple building systems and assemblies are replaced simultaneously. For example, if lighting and HVAC systems are replaced, the HVAC system designer can take into account the reduced cooling load achieved by the lighting retrofit, resulting in a smaller cooling system. Though this can also occur in the staged approach, the whole-building approach is generally more conducive to identifying such opportunities.

The whole-building approach typically involves architects, design engineers, and potentially commissioning providers working together as part of an integrated design process, where the various design disciplines coordinate closely to design and specify systems and assemblies that will meet the project needs as well as result in minimal energy use (Energy Design Resources 2002). Retrofit systems are designed in concert, rather than as a sum of individual parts, and the final design is evaluated using life cycle economics. This process aligns well with aggressive energy savings targets.

4.2 Staged Approach

The key to the staged upgrade approach is to complete improvements to buildings systems in the order that reflects the influence of one system on another. For example, cold air and vapor losses from refrigerated cases add heating loads to grocery store spaces that must be met by the space heating equipment during the winter. By first upgrading refrigerated cases, future HVAC system improvements can be properly sized and better optimized in a subsequent stage of the project. Under the staged approach, projects are usually implemented in the order shown in Figure 4–1. It may be appropriate to skip EBCx for subsystems or components that will be replaced during Step 2, if the time between the two steps is short (less than 1 year), because the energy savings will likely be small over such a short timeframe. It may also be valuable to install an EMS during Step 1 to add flexibility in the selection of future retrofit measures and to increase their effectiveness.

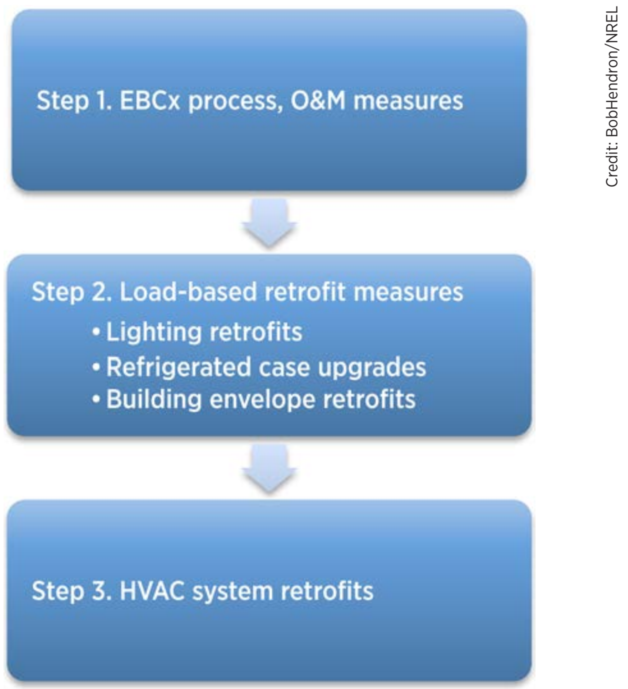

Figure 4–1 Recommended project phases for a staged approach to energy efficiency upgrades

EBCx optimizes the performance of existing equipment, which provides a better baseline for determining which retrofits will be cost effective. In some cases, EBCx can improve the cost effectiveness of subsequent measures by showing where systems can be downsized when operated efficiently. In addition, the typically low-cost and quick returns of O&M measures make them an obvious first step for grocery store owners who want to see immediate results with limited capital expense. The risk to completing EBCx first is that the system optimization may need to be repeated as subsequent retrofits are completed. Carefully documenting EBCx measures can reduce this effort. A more detailed discussion of EBCx is presented in Section 3.

After EBCx, measures that affect heating and cooling loads should be considered. A variety of measures fall into this category. Some directly reduce energy consumption with cooling savings as an indirect benefit, such as replacement of inefficient lighting. Others, such as sealing compressor room leaks, solely reduce energy through indirect means. What they have in common is that they all have an impact upon the building's heating and cooling demands. The more efficient lights will emit less wasted energy into the building as heat, and therefore reduce the building's cooling needs and potentially increase its heating needs. The envelope improvements may reduce solar heat gain and thereby lower cooling needs. Eliminating losses from refrigerated cases also impacts the building's heating and cooling loads. By first completing retrofits to these systems, the next stage of retrofits can be optimized for the new heating and cooling demands.

In typical retrofit projects, it may be standard practice to progress from the measures affecting heating and cooling loads to a one-to-one replacement of components in the heating and cooling system. A 10-ton rooftop unit is replaced with a more efficient 10-ton rooftop unit. In this common approach, efficiency is no doubt improved, but a big cost saving opportunity is missed. A carefully planned approach will look deeper, to identify where the heating and cooling system can be resized to meet the demand of the optimized building. An engineering analysis may show that the 10-ton rooftop unit could be replaced with an efficient 7½-ton rooftop unit. Not only does the smaller rooftop unit cost less, but it also performs better because it is a better match to the optimized building's load.

Case Study 5: Davis Food Co-op

Quick Facts

- Facility Name: Davis Food Co-op
- Facility type: Supermarket
- Location: Davis, California
- Year built: 1959
- Gross square footage: 25,000

Credit: Bija Young/Davis Food Co-op, used by permission

Davis Food Co-op is an independent grocery store in Davis, California. The store prides itself on its connection to the community that comprises it membership and on its commitment to reduce its impact on the environment.

One way the store fulfills its mission is by minimizing its energy consumption and the related financial and environmental costs. After completing a major renovation in 2008, the store's leadership continued to seek cost-effective energy savings.

The Co-op worked with a representative from EnergySmart Grocer, a utility-funded program that provides technical and financial assistance to implement energy efficiency improvements in the Pacific Gas & Electric service territory. The Co-op decided to update the store's refrigeration control system and to replace its fluorescent refrigeration case lighting with a light-emitting diode (LED) system.

"Reducing our carbon footprint results in customers who are pleased that we put our environmental values into action."

— Eric Stromberg, General Manager

The entire project was completed by Hussmann Corporation in the spring of 2011. First the refrigeration system controls were updated to allow floating head and suction pressure control strategies. Then all the case lighting in the frozen food aisle was converted to LED technology.

The LED system not only requires less energy, it also switches on and off instantly. This feature allowed for the use of motion sensors that dim the lighting when no shoppers are detected in the area.

Eric Stromberg, the Co-op's General Manager, says that he appreciates the support received from the utility-sponsored energy efficiency program and saw the retrofit as a way to lower operating costs and a chance to put the Co-op's environmental values into action. An analysis of the store's utility bills three months after the project was completed indicates it is on track to save almost $20,000 in the first year alone.

Key Measures

1. *Floating head and suction pressure control strategies on refrigeration system, 144 hp (compressor)*
2. *LED Lighting in Reach-in Refrigerated Display Cases, 265 ft of LED*
3. *Motion Sensor Control of Lighting in Reach-in Refrigerated Display Cases, 265 ft of LED*

Equipment Costs	Installation Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$12,386	$11,205	$23,591	$13,425	$10,166
Energy $ Savings		**Annual Return on Investment (Excluding Incentives)**		**Simple Payback**
$19,981/yr		197% (85%)		6 months
Energy Use Before	**Energy Use After**	**Energy Use Intensity (EUI) Before**	**Energy Use Intensity (EUI) After**	**% Site Savings**
6,370 MMBtu/yr	5,671 MMBtu/yr	255 kBtu/ft^2	227 kBtu/ft^2	11%

Energy managers must tailor their plans to match the needs of their stores, so the staged approach presented here may not always fit. Departing from the stages shown here may be necessary at times, to deal for example with financial constraints or store operations. It is a good idea for energy managers to at least investigate the potential for implementing retrofit measures that will impact heating and cooling loads before embarking on a large-scale HVAC system retrofit. That way, the tradeoffs that are being made can be clearly examined.

The primary benefit of the staged approach is that the upfront project costs can be spread over a longer period. Retrofits with quick paybacks are typically completed first, and it may be possible to use the savings from these early projects to justify the costs of subsequent stages. For this reason, the staged approach may be ideal for organizations unable to justify one large upfront cost for a whole-building retrofit project. Case Study #5 shows how Davis Food Co-op followed up a major renovation with a set of refrigeration system upgrades to help meet its goals.

4.3 Leveraging Opportunities for Higher Savings

Several key leverage points during a grocery store's life cycle offer opportunities to achieve much higher energy savings, regardless of whether a whole-building or staged approach is being applied. Table 4–1 lists some of these key opportunities that can fundamentally change the economics for a retrofit project, helping to meet more aggressive energy savings targets of 50% and beyond.

Table 4–1 Special Opportunities for Achieving Higher Energy Savings

Point in Building Life Cycle	Opportunity
Redevelopment or market repositioning	Redevelopment or market repositioning will require (perhaps over several years) significant capital expense to which the cost of a retrofit would be incremental and likely small in comparison.
Roof, window, or siding replacement	Planned roof, window, and siding replacements provide opportunities for significant improvements in daylighting and efficiency at small incremental cost, providing the leverage for envelope improvements that reduce loads and therefore the cost of replacing major equipment such as refrigeration systems and lighting.
End (or near end) of life HVAC, lighting or other major equipment replacement	Major equipment replacements provide opportunities to address the envelope and other building systems as part of a comprehensive retrofit package. After reducing thermal and electrical loads, the marginal cost of replacing the major equipment with much smaller equipment (or no equipment at all) can be negative.
Upgrades to meet code	Life safety upgrades may require substantial disruption and cost, enough that the incremental investment and effort to radically improve the building efficiency becomes not only feasible but also profitable.
New owner or refinancing	New ownership or refinancing can put in place attractively financed building upgrades as part of the transaction, upgrades that may not have been possible at other times.
Major occupancy change	A company or tenant moving a significant number of people or product into a building or major turnover in square footage presents a prime opportunity for a comprehensive retrofit, because (1) a comprehensive retrofit can generate layouts that improve energy and space efficiency, and can create more leasable space through downsizing mechanical equipment; and (2), ownership can leverage tenant investment in the fit-out.
Building greening	An owner- or tenant-driven desire to achieve green building or energy certification may require significant work on the building and its systems, which may then make a more aggressive retrofit economical.

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Table 4–1 Special Opportunities for Achieving Higher Energy Savings (cont'd.)

Point in Building Life Cycle	Opportunity
Large utility incentives	Many utilities will subsidize the cost for a retrofit project, covering initial evaluations through construction. In some regions, the incentives might be large enough to make more retrofit measures economical.
Fixing an "energy hog"	There are buildings, often unnoticed, with such high energy use or high energy prices (perhaps after a major rate increase), that comprehensive retrofits have good economics without leveraging any of the factors above.
Portfolio planning	As part of an ongoing energy management plan for a portfolio of buildings, an owner may desire a set of EEMs to be replicated across the portfolio. These can be developed from an expansive retrofit of a typical building.

In addition to identifying solutions that create grocery store value, the retrofit process will reveal ways to piggyback EEMs onto scheduled building equipment or component replacements, thereby reducing the cost and inconvenience of standalone EEMs. For example, the high capital cost of overhauling refrigerated cases to be more efficient can have negative NPV. However, if the cases must be replaced or overhauled anyway because they have reached their end of life, the cost of making them more efficient is only incremental to the replacement cost. Case Study #6 illustrates the benefits of leveraging a store expansion and later a remodeling effort to implement a comprehensive energy retrofit project at a King Soopers in Aurora, Colorado.

A retrofit project can also be used as a tool for identifying EEMs that are tailored to the entire grocery store chain—not just one facility. Key elements to such an approach are grouping similar buildings together and conducting a pilot whole-building retrofit of the typical buildings. The more similar the typical buildings are to the group of buildings they represent, the more informative the findings will be and the less analysis is needed in the future.

To create groups of similar buildings, one should sort all the buildings in the portfolio by factors such as:

- Age and condition of building systems and components
- Building size and shape
- HVAC system and envelope type
- Climate and microclimate
- Building functions.

One typical building from the group of similar buildings should then be selected for the pilot renovation. This retrofit should address at a minimum the following questions for all the buildings it represents:

- *Which groups of integrated EEMs were particularly cost effective?* The pilot retrofit team will identify the specifications, capital cost, and return on investment for one or more groups of integrated EEMs. This information will be critical for planning a larger and long-term investment across the rest of the portfolio.
- *Which groups of integrated EEMs will require further design work to be replicated?* A subset of the total identified EEMs may require tailoring to specific buildings. It will be important to indicate in the portfolio plan which EEMs will require this extra design work. For instance, an EEM that links the heating controls to the lighting occupancy sensors may not require electrical design work, because the wiring is similar across the portfolio of buildings. On the other hand, replicating an EEM to install skylights may require some lighting design work to ensure correct placement for optimal light distribution.
- *Which implementation team members were particularly creative or integrative?* The retrofit project can also be a proving ground for the team charged with reducing energy across the portfolio. The team should include talented people who are not afraid to be unconventional and who want to go beyond incremental energy savings.

Case Study 6: Kroger Co. (King Soopers) Store No. 016— Aurora, Colorado

Quick Facts

- Facility Name: King Soopers Store 016
- Facility type: Grocery Store
- Owner: The Kroger Co.
- Location/climate zone: Aurora, Colorado (Zone 5B)
- Year built: 1996, expanded in 2005
- Gross square footage: 74,400 (originally 69,500)

Credit: RMI, used by permission

As part of The Kroger Company's overall commitment to energy efficiency (average store electricity use has fallen more than 30% since 2000), King Soopers in Aurora, Colorado embarked upon a long series of projects and programs to reduce energy expense. The store was retro-commissioned in February 2003 and, nine months after a small expansion, re-commissioned in August 2006 and again in August 2008 and August 2011.

> *"The energy efficiency measures we have installed in all of our stores, including this store, help us maintain competitive prices and offer a comfortable shopping experience "*
>
> — Leonard Micek, Energy Engineer, King Soopers

Specific EEMs included anti-sweat heaters controls and implementation of a temperature-difference control strategy for condensing; installation of strip curtains at walk-in cooler doors; variable-speed drives for the refrigeration compressors, condensers and air-curtain motors; LEDs in reach-in doors/coolers and variable-speed motors for refrigerated walk-in and display case evaporator fans; upgrade of refrigeration and HVAC controls; and installation of vending machine controls.

The King Soopers store implemented an overall "Lighting ReInvention" after a major remodel in 2011 to reduce wattage and to improve general lighting effectiveness. Planned projects include 28-W overhead lamps (replacing 30-W with same amount of light), LEDs for fresh meat cases and tracks, LEDs for walk-in coolers and freezers, and energy-efficient wrapper-sealer machines.

Key Measures

1. *~100 unit-cooler EC motors installed September 2005 and ~80 more installed August 2008*
2. *~220 LED sticks installed March 2010*
3. *Seven variable speed drives (VSDs) installed: 4 in January 2006, 1 in October 2008, and 3 in June 2010*

Audit Costs	Equipment Costs	Installation Costs	Total Costs
$16,300	$67,200	$54,500	~$120,000

Energy $ Savings	Total Savings	Simple Payback
~$120,000/yr	~$120,000/yr	1 year

Energy Use		Simple Payback		
Before	After	Before	After	% Site Savings
4.26 million kWh/yr	2.96 million kWh/yr	55 kWh/ft²/yr	33.7 kWh/ft²/yr	30.4% since 2000

- *What corporate or institutional policies would help or hinder implementation of the EEMs?* In many cases, decision makers in a grocery store chain may not realize that their policies can hinder or encourage efficiency. A thorough examination of a single building can reveal institutional impediments and enablers.

4.4 Retrofit Measure Summary Table

The EEMs listed in Table 4–2 were identified as the best retrofit options for grocery stores, and are examined in detail in Appendix F. The table shows the relevance of each measure to the five locations addressed in the example building analysis. For other locations, extrapolations may be necessary. These measures were carefully selected based on input from experts in energy retrofits for grocery stores. Handbooks, manuals, technical papers, and other external resources were consulted extensively, along with available case studies describing successful retrofit projects. Additional measures may be appropriate for specific projects, and many of these ideas are also presented for consideration at the end of Appendix F.

Table 4–2 Retrofit Measure Summary Table

System	Measure Description	Applicable to:					Stage (see Section 2.2)	Section
		Miami	Las Vegas	Seattle	Chicago	Duluth		
Lighting	Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts	✓	✓	✓	✓	✓	2	F.1.1
	Replace incandescent ambient lighting with compact fluorescent lamps (CFLs) and accent/display lighting with ceramic metal halide	✓	✓	✓	✓	✓	2	F.1.2
	Replace refrigerated display case lighting with LEDs	✓	✓	✓	✓	✓	2	F.1.3
	Install wireless motion sensors for lighting in rooms that are used intermittently (break rooms, storage areas), and for lighting in refrigerated display cases	✓	✓	✓	✓	✓	2	F.1.4
	Install timer controls for nonessential lighting when building is unoccupied	✓	✓	✓	✓	✓	2	F.1.5
	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient	✓	✓	✓	✓	✓	2	F.1.6
	Increase the availability of daylight with skylights, tubular daylighting devices, or hybrid solar lighting that collects and distributes sunlight via optical fibers to the building interior	✓	✓	✓	✓	✓	2	F.1.7

Building Retrofits

Table 4–2 Retrofit Measure Summary Table (cont'd.)

System	Measure Description	Applicable to: Miami	Las Vegas	Seattle	Chicago	Duluth	Stage (see Section 2.2)	Section
Refrigeration and Cooking	Install high-efficiency ECM evaporator fan motors	✓	✓	✓	✓	✓	2	F.2.1
	Install night curtains to reduce load on open refrigerated cases	✓	✓	✓	✓	✓	2	F.2.2
	Install doors on open refrigerated cases	✓	✓	✓	✓	✓	2	F.2.3
	Install controls to disable ASHs when dew point is low		✓	✓	✓	✓	2	F.2.4
	Install variable-speed drives on condenser fans for the refrigeration system	✓	✓	✓	✓	✓	2	F.2.5
	Install evaporative condensers for refrigeration systems		✓				2	F.2.6
	Install strip curtains and weather seal walk-in freezer doors	✓	✓	✓	✓	✓	2	F.2.7
	Install compressor unloaders with electronic controls for capacity control	✓	✓	✓	✓	✓	2	F.2.8
	Install smart defrost controller in walk-in freezers and low-temperature cases	✓	✓	✓	✓	✓	2	F.2.9
	Install walk-in freezer "door open" alarms and automatic door closers to reduce time when doors are left open	✓	✓	✓	✓	✓	2	F.2.10
	Replace kitchen/deli/bakery appliances with ENERGY STAR models	✓	✓	✓	✓	✓	2	F.2.11
	Replace commercial refrigerators, freezers, and ice makers with ENERGY STAR models	✓	✓	✓	✓	✓	2	F.2.12
	Install variable-speed drive kitchen hood exhaust fans with demand control ventilation (DCV).	✓	✓	✓	✓	✓	2	F.2.13

Table 4–2 Retrofit Measure Summary Table (cont'd.)

System	Measure Description	Applicable to: Miami	Las Vegas	Seattle	Chicago	Duluth	Stage (see Section 2.2)	Section
HVAC: Heating & Cooling	Replace electric resistance furnaces with water source heat pumps	✓	✓	✓	✓	✓	3	F.3.1
	Install an EMS to control, track, and report energy use	✓	✓	✓	✓	✓	3	F.3.2
	Upgrade electronic controls	✓	✓	✓	✓	✓	3	F.3.3
	Install a dry-bulb air-side economizer (differential enthalpy in humid climates)	✓	✓	✓	✓	✓	3	F.3.4
	Install a desiccant wheel dehumidification system	✓		✓	✓		3	F.3.5
	Add refrigeration system heat recovery coils for hot water or space heating		✓	✓	✓	✓	3	F.3.6
	Replace inefficient motors with right-sized National Electric Manufacturers Association (NEMA) premium efficiency	✓	✓	✓	✓	✓	3	F.3.7
	Convert constant volume or dual duct air handling systems to variable air volume (VAV)	✓	✓	✓	✓	✓	3	F.3.8
HVAC: Ventilation	Upgrade to DCV to reduce outdoor airflow during partial occupancy	✓	✓	✓	✓	✓	2	F.4.1
	Add energy recovery to ventilation system	✓	✓		✓	✓	2	F.4.2
	Install variable-speed drives for HVAC supply fans and adjust the ventilation rates as needed to meet local code requirements	✓	✓	✓	✓	✓	2	F.4.3

4.5 Recommended Retrofit Packages

The following sections identify cost-effective (positive NPV) retrofit packages for the example grocery store in each of five geographic locations. All EEMs were selected from those listed in Table 4–2 discussed in detail in Appendix F. The analysis was performed in the context of a whole-building retrofit, with all measures implemented in the first year. These packages are not necessarily optimal, but are representative of the type of package that can be very cost effective in a typical grocery store even before financial incentives are considered. The process for selecting the EEMs for inclusion in each package is described in Section 1.4.

At-a-Glance Results

Table 4–3 summarizes the results of the energy and financial analyses of the recommended packages of retrofit measures, and identifies which measures are included for each climate zone.

Table 4–3 Recommended Retrofit Packages—Results of Common Metrics*

Location	EUI (kBtu/ft^2)			Energy Cost/ft^2		
	Baseline	Post-Retrofit	Percent Reduction	Baseline	Post-Retrofit	Percent Reduction
Miami (Hot & Humid)	203	160	21.0%	$ 4.54	$ 3.56	21.5%
Las Vegas (Hot & Dry)	219	168	23.3%	$ 4.67	$ 3.48	25.4%
Seattle (Marine)	238	155	34.5%	$ 4.97	$ 3.48	30.0%
Chicago (Cold)	265	176	33.5%	$ 5.86	$ 3.93	32.9%
Duluth (Very Cold)	301	200	33.3%	$ 5.70	$ 3.78	33.7%
Average	245	172	29.1%	$ 5.15	$ 3.65	28.7%

*Energy savings for retrofit packages do not include the effects of EBCx.

The retrofit measures included in the recommended packages are shown in Table 4–4.

Table 4–4 Measures Included in the Recommended Retrofit Packages

System	Measure Description	Climate Zone	Section
Lighting	Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts	Hot & humid	F.1.1
Lighting	Replace incandescent ambient lighting with CFL and accent/display lighting with metal halide	All	F.1.2
Lighting	Replace refrigerated display case lighting with LEDs	All	F.1.3
Lighting	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient	Hot & humid, hot & dry	F.1.6
Refrigeration	Install high efficiency EC evaporator fan motors	All	F.2.1
Refrigeration	Install doors on open refrigerated cases	Marine, cold, very cold	F.2.3
Refrigeration	Install controls to disable anti-sweat heaters when dew point is low	Cold, very cold	F.2.4
Refrigeration	Install strip curtains and weather seal walk-in freezer doors	All	F.2.7
HVAC	Install variable speed drive kitchen hood exhaust fans with demand control ventilation	All	F.2.13
HVAC	Replace inefficient motors with right-sized NEMA premium efficiency	All	F.3.7
HVAC	Convert constant volume or dual duct air handling systems to variable air volume	All	F.3.8
HVAC	Upgrade to demand control ventilation to reduce outdoor airflow during partial occupancy	All	F.4.1

Rationale for Recommended Measures

The measures were chosen for inclusion in each retrofit package based on their high energy savings potential, cost effectiveness, and relatively simple implementation in the context of the example grocery stores. These are representative of measures that building owners typically implement solely to realize energy cost savings. These measures may be very cost effective to implement when equipment is being replaced anyway, but owners also often find it pays to implement these measures before the affected equipment has reached the end of its useful life—that way they may have more time to consider multiple options. Note that other measures from Table 4–2 could be included as part of a retrofit package, depending on the particular store being retrofit. Additional measures that may be considered are included at the end of Appendix F.

The EEMs included in each retrofit package either add functionality, replace a system component with a more efficient version, or modify a system to operate more efficiently. These typically do not require an integrated design process as part of implementation, and usually do not represent changes to system types. They can be implemented with minimal disruption to the grocery store's normal operations. A more integrated design approach would be likely to reveal more opportunities and achieve higher savings. Further discussion of the process for selecting retrofit packages can be found in Section 1.4.

Energy Savings

The recommended retrofit packages are estimated to result in savings of more than 29% of site energy use, based on an analysis of each package when applied to the example grocery store. As shown in Table 4–5, each climate zone shows significant energy savings, with only small variation between the zones. For the energy savings and NPV of retrofit measures applied individually, see the more detailed analytical results in Appendix C.

Table 4–5 Recommended Retrofit Package Energy Savings Results*

Location	Electricity Savings (annual kWh)	Electric Demand Savings (peak kW)	Gas Savings (annual therms)	Site EUI Savings (kBtu/ft²)	Savings as % of Total Site Usage	Savings as % of Total Source Usage
Miami (Hot & Humid)	562,475	109	5	42.7	21.0%	21.7%
Las Vegas (Hot & Dry)	681,114	142	-313	51.0	23.3%	26.9%
Seattle (Marine)	671,716	82	14,218	82.5	34.5%	32.4%
Chicago (Cold)	784,277	124	13,205	88.8	33.5%	33.6%
Duluth (Very Cold)	810,214	107	17,641	100.7	33.3%	34.4%

* Energy savings for retrofit packages do not include the effects of EBCx.

Financial Analysis

The financial metrics associated with the retrofit packages for each climate zone are shown in Table 4–6. For the financial metrics of all individual retrofit measures, see Appendix C. Each of the retrofit packages has a fast simple payback and positive NPV. We recognize that these packages are very aggressive, and it may be challenging for a grocery store owner to raise the initial capital even if the measures are cost effective.

Table 4–6 Retrofit Recommended Package Financial Analysis Results*

Location	Total Measure Costs	Total Energy Cost Savings	O&M Cost Savings	Total Annual $ Savings**	Simple Payback (Years)	NPV
Miami (Hot & Humid)	$388,127	$44,031	$43,409	$63,033	6.2	$333,079
Las Vegas (Hot & Dry)	$340,298	$53,505	$43,033	$68,769	4.9	$421,840
Seattle (Marine)	$468,296	$66,803	$44,228	$83,142	5.6	$395,920
Chicago (Cold)	$492,408	$86,181	$44,435	$96,243	5.1	$517,448
Duluth (Very Cold)	$455,245	$66,026	$43,861	$81,904	5.6	$399,412

*Energy savings for retrofit packages do not include the effects of EBCx.
**Including tax implications

4.6 Additional Considerations

The retrofit measures included in the recommended packages, along with the additional measures discussed in Appendix F, provide a starting point for retrofit options that should be considered for most grocery stores. However, not all measures will be applicable to all stores, and additional measures may be applicable to a specific building. Some are listed at the end of Appendix F.

Building owners considering implementing specific retrofit measures should consult the detailed description of the retrofit measures in Appendix F to gain an understanding of the application of each measure to grocery stores in various climate zones.

When evaluating retrofit measures for application to a specific store, the following questions should be considered to help narrow the options to a manageable number:

- *Are the equipment and assemblies in the building nearing the end of their useful lives?* By identifying and evaluating equipment that is nearing the end of its life before it has failed, owners can evaluate multiple retrofit options considering all potential costs and benefits instead of just replacing the equipment with like equipment once it fails. Case Study 7 illustrates how a Shopper's Corner store in Santa Cruz, California, took advantage of the opportunity presented by refrigerated cases that were at the end of their useful lives.
- *Is the measure relevant to building operations?* The capabilities of the service contractors and/or operations staff should be considered when evaluating measures. Do the staff members have the necessary skills and knowledge to support the measure? If not, is there additional training that they can receive?
- *Are there load-based retrofits that can be considered and implemented before HVAC retrofits?* Using a staged approach for retrofits can produce greater savings and increased performance than just replacing systems and components with like-sized equipment. Implementing load-based retrofits first, which have an impact on the heating and cooling loads, can help lower the cost of subsequent HVAC retrofits, improve the performance of HVAC systems, and reduce the overall energy use of the building.
- *Have the building characteristics changed over time in a way that could impact the retrofit?* When replacing equipment, it is important to evaluate whether the equipment should be replaced with like-sized equipment. As load-based retrofits occur over time in a building (e.g., envelope, lighting), the load on the HVAC and refrigeration equipment can change, which can impact the necessary size of the equipment. Also, if building operating criteria have changed over time, this can also impact the new equipment. For example, if required lighting levels or the store's layout has changed, this could impact the number and layout of fixtures installed in a lighting retrofit.

- *Do energy codes apply to the retrofit?* Energy codes have minimum efficiency standards for most equipment installed in retail buildings. Before embarking on a retrofit project, it is important to ensure that the equipment being installed as part of the retrofit meets or exceeds local energy codes.
- *Are there incentives that can help increase the cost effectiveness of a particular retrofit?* Many electric and gas utilities offer incentives for replacing old, inefficient equipment with new equipment that exceeds the code energy efficiency requirement. The local utility can provide information about incentive programs.
- *Has the building's use changed since it was originally constructed?* If a building's use has changed significantly since it was originally constructed, its systems and assemblies are likely not optimized to suit its current needs. A whole-building retrofit project presents a perfect opportunity to evaluate the current systems and assembly types, and presents options for alternate systems and assemblies that may be more suited to the building's needs.
- *Do retail operations need to continue during the retrofit period?* Retrofits often include major renovations to building systems and assemblies. Impact on the operation of the store must be considered, and this aspect can be a limiting factor in the depth that a retrofit can go. If the store can be closed for the retrofit construction period, the level of retrofit can be deeper than if the store must remain open during the retrofit construction period.
- *Will the project be commissioned?* Commissioning is highly recommended for all retrofits. It provides assurance that the project was designed and constructed to meet the stated requirements. The commissioning program can start during a retrofit's design phase and proceed through construction, to help the project team match the design with the needs of the building, and to help ensure the long term maintainability of the facility. Commissioning is often most useful at the start of a project, when it can have the biggest impact.

4.7 Additional Resources

Use these resources for more detailed information about retrofit strategies for grocery stores and supermarkets.

ENERGY STAR *Building Upgrade Manual*: The building upgrade manual provides technical recommendations for retrofits to existing buildings, with a specific chapter dedicated to grocery stores. *www.energystar.gov/index.cfm?c=business.bus_upgrade_manual*

Rensselaer Polytechnic Institute (RPI) Lighting Research Center. This website provides a variety of resources for evaluating lighting retrofits. *www.lrc.rpi.edu/researchAreas/outdoor.asp*

Rocky Mountain Institute's Retrofit Depot: Online resource for case studies, advice, and tools and resources related to retrofit project implementation. *www.rmi.org/retrofit_depot*

ASHRAE, "Energy Efficiency Guide for Existing Commercial Buildings: The Business Case for Building Owners and Managers," 2009: Includes guidance on planning for retrofits, specific methods for improving energy performance, and making the business case for energy retrofits.

ASHRAE, *Energy Efficiency Guide for Existing Commercial Buildings: Technical Implementation Guide*, 2011: Provides technical implementation considerations for common retrofit measures, including many of the measures discussed in this guide.

Doty and Turner, *Energy Management Handbook*, 2012: Provides detailed coverage of effective energy management strategies. Available for purchase online.

Wulfinghoff, *Energy Efficiency Manual*, 1999: A primary reference, how-to guide, and sourcebook for energy efficiency upgrades in all building types.

Case Study 7: Shopper's Corner, Santa Cruz, California

Quick Facts

- Facility Name: Shopper's Corner
- Facility type: Grocery
- Owner: Beauregard Family
- Location: Santa Cruz, California
- Year built: 1928
- Gross square footage: ~10,000
- Project Team: PECI, Hussman Corp., Trip Cheney

Credit: PECI, used by permission

Shopper's Corner, a family-owned independent grocery store since 1938, saved 15% energy cost with less than a 10-year payback in PECI's EnergySmart Grocer Program, supported by Pacific Gas & Electric Co. Located in Santa Cruz, California, Shopper's Corner achieved most of the savings via measures installed in 2010 over the course of just two days.

"It was a necessary improvement. I think more businesses need to take responsibility for the impact their business has on the environment."

— Andre Beauregard
Owner, Shoppers Corner

EnergySmart Energy Analyst, Matt di Cicco, offered and performed in 2008 a free energy audit. Storeowner Jim Beauregard and his son Andre had been planning to repair their existing refrigerated cases, but decided instead to completely replace the units with more efficient ones. The new reach-in and open refrigerated cases, which include LED lights, are supported by a multiplex compressor system with controls for efficiency.

EnergySmart Grocer's di Cicco worked closely with the contractor during the remodel to ensure the project went smoothly. The team worked overtime to ensure that the installations were made with as little interruption as possible to sales.

The new refrigeration system is more reliable and has resulted in a maintenance cost decrease. The Beauregards were initially skeptical of the projected energy savings, but billing history analysis completed by EnergySmart Grocer in 2011 showed 15% annual energy cost savings compared to the previous year. In addition to all the cost savings, the Beauregards are pleased by local shoppers noticing the efficiency upgrades and supporting their efforts. The Beauregards financed $1 million through Comerica to pay for the project and will repay the loan over 10 years. Most of the $1 million cost was offset by what they would have spent on business-as-usual upgrades anyway—hence, a less than 10-year payback.

Key Measures

1. *LED case lighting, reach-in and open cases, 1,012 linear feet installed (42,342 kWh saved)*
2. *Floating head pressure and floating suction pressure controls, multiplex system, 46 horsepower (37,000 kWh)*
3. *Strip curtains, walk-in refrigerated coolers and freezers, 105 ft² (39,060 kWh)*

Audit Costs	Equipment Costs	Installation Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$0	$850,000	$170,000	$1,200,000	$9,540	$1,010,000

Energy $ Savings	Total $ Savings	% Site Savings	Simple Payback
~$15,000/yr	~$15,000/yr	23%	<10 years (11 years excluding incentives)

Energy Use (electricity only) Before	Energy Use (electricity only) After	Energy Use Intensity (electricity only) Before	Energy Use Intensity (electricity only) After	% Site Savings
561,840 kWh/yr	477,600 kWh/yr	56.2 kWh/ft²/yr	47.8 kWh/ft²/yr	15%

Building Retrofits

ASHRAE, Standard 189.1, 2009: Provides minimum requirements for the siting, design, construction, and plan for operation of high-performance green buildings. Available for purchase online. *www.ashrae.org*

Energy Design Resources Daylighting Design website. Provides a series of free design briefs, guides, and case studies for optimizing daylighting in commercial buildings. *www.energydesignresources.com/technology/daylighting-design.aspx*

New Buildings Institute (NBI), Advanced Lighting Guidelines, 2010: Provides practical design information on lighting technologies for high-performance buildings. Available for purchase online. *www.algonline.org*

"Main Street Net Zero Energy Buildings: The Zero Energy Method in Concept and Practice." Torcellini, Paul, Shanti Pless, Chad Lobato, David Okada, Tom Hootman. Proceedings of ASME 2010 4th International Conference on Energy Sustainability. *http://www.nrel.gov/sustainable_nrel/pdfs/47870.pdf*

Life Cycle Cost Analysis: Is it Worth the Effort? Buys, Aaron, Michael Bendewald, Kendra Tupper. Rocky Mountain Institute. *http://rmi.org/rmi/Library/2010-24*

EPA, *Building Upgrade Manual*, 2008: A strategic guide for planning and implementing a profitable energy saving building upgrade following a five-stage process. Available for free download online. *www.energystar.gov/*

BOMA, BEEP (BOMA Energy Efficiency Program): A training program targeted at commercial real estate professionals on how to increase and maintain energy performance of commercial facilities. More information available at *www.boma.org/beep*.

American Institute of Architects, "Integrated Project Delivery: A Guide," 2007: A tool to assist owners, designers and builders to move toward integrated models and improved design, construction and operations processes. Available for free download online. *www.aia.org*

LBNL, "Tips for daylighting with windows," 1997: Includes guidelines on cost-effective approaches to exterior zone lighting design. Available for free download online. *www.lbl.gov*

5 Measurement and Verification

Determining the actual savings from an energy efficiency retrofit project is often important to demonstrate its effectiveness. Because savings represent the absence of energy use, they cannot be directly measured. Making simple comparisons of energy use before and after a retrofit is typically insufficient to accurately estimate energy savings, because it does not account for routine fluctuations in weather, building occupancy, and other factors impacting use. M&V is the practice of measuring energy use and computing savings by making adjustments to account for these fluctuations.

M&V activities include conducting site surveys, metering energy use parameters, monitoring independent variables, executing engineering calculations, and reporting. The industry guideline for conducting these activities is the International Performance Measurement and Verification Protocol (IPMVP) (EVO 2010). It includes a framework for best practices in conducting M&V and outlines four general approaches or options. Following these guidelines allows for transparent and reliable reporting of project savings. See Table 5–1 for definitions of key M&V concepts and terms.

Table 5–1 M&V Terminology

Key IPMVP M&V Terminology	
EEM	A design or operational improvement made to a facility, system, or piece of equipment that reduces energy use or peak demand.
Measurement boundary	A hypothetical boundary drawn around equipment and/or systems to isolate its energy or mass flows relevant for determining energy savings.
Independent variable	A parameter that is expected to change regularly and have a measurable impact on the energy use of the facility, system, or piece of equipment.
Baseline period	The period of time chosen to represent operation of the facility or system before implementation of the energy efficiency project.
Baseline energy	The energy use occurring during the baseline period, and its relation to driving independent variables.
Adjusted baseline energy	The energy use of the baseline period, adjusted using regression analysis or simulation modeling to a different set of operating conditions, typically those of the post-install conditions.
Savings	Typically, the adjusted baseline energy costs minus the post-install energy costs.

Credit: RMI

Some retrofit projects may have an explicit need to include a savings verification component as part of their M&V efforts, such as those funded through performance contracts, pursuing LEED M&V credits, or participating in utility incentive programs. Other projects without these requirements may choose to focus their M&V activities on ensuring the building is performing as intended and has a high potential to achieve savings and exclude the actual quantification of savings. M&V is inherently flexible. The approach selected should take into account the objectives for conducting the M&V and the value that it can provide.

5.1 Planning

For an owner, it is important to determine early in the project planning process if M&V will be part of the project. If savings are to be verified, special planning is required and may involve metering and measurement activities to establish the baseline conditions before implementing any changes to the facility.

One key M&V issue to consider is the level of accuracy of the reported savings, which influences the scope and level of rigor of the M&V activities. Proper planning can help integrate the verification activities into the project and potentially leverage related tasks, such as commissioning. A key goal is to keep the cost of the verification activities in line with the scope and needs of the project. A typical timeline for M&V activities is shown in Figure 5–1.

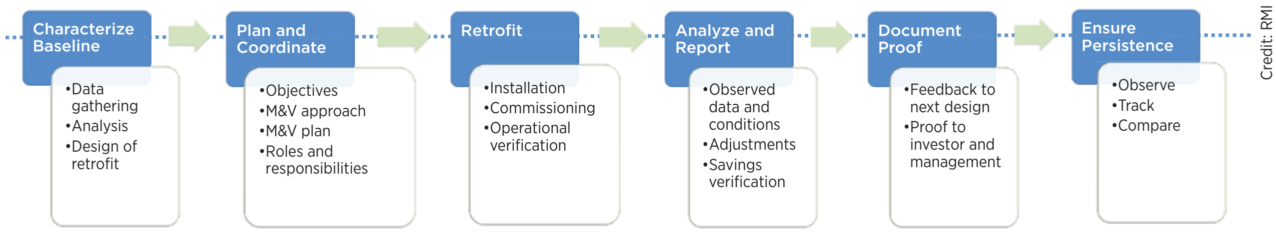

Figure 5–1 M&V timeline

5.2 Overview of Approaches

The two essential components of M&V are:

- **Operational verification (OV).** This verifies that the EEMs are installed and operating properly. Activities include visual inspection, data trending, and functional testing. This is accomplished through comprehensive commissioning of all affected systems and supplemental data-driven activities (e.g., monitoring and tracking). Setting clear expectations for equipment or system performance is helpful for directing effective OV efforts. OV should be conducted even if savings verification activities are not.
- **Savings verification (SV).** This involves the calculation of energy savings resulting from the installed EEMs. Industry-accepted SV procedures are covered by the IPMVP.

OV and commissioning should be completed before the start of the M&V period that savings are determined for. This ensures that the full savings attributed to EEMs and control and operation improvements are captured.

The four SV options defined by the IPMVP are:

- **Option A—Retrofit isolation with partial measurement.** Equipment is isolated and key parameters affected, such as load or hours of operation, are spot measured before and after the retrofit.
- **Option B—Retrofit isolation with full measurement.** Equipment is isolated and all energy-related parameters are measured before and after the retrofit for a sufficient period of time to characterize the range of operation. This strategy is preferred over Option A for systems with more variable energy use.
- **Option C—Whole building.** Whole-building utility billing data are correlated with independent variables, such as outdoor air temperature. Baseline and post-retrofit energy use is adjusted to the same set of conditions and compared to determine energy savings.
- **Option D—Calibrated simulation.** Energy use is modeled both before and after the retrofit using specialized building energy simulation software. The post-install model is calibrated so it accurately reflects actual building energy use. The baseline model is adjusted to represent the same set of operating conditions as the post-install model. Savings are determined by comparing costs predicted by the adjusted baseline model with the calibrated post-install model or actual energy cost.

These options are grouped into two general categories: retrofit isolation (Options A and B) and whole building (Options C and D). One of the fundamental differences between these approaches is where the savings boundary is drawn (See Figure 5–2). Retrofit isolation strategies focus on the individual retrofit and its impact on a specific piece of equipment or system. Whole-building methods are based on either utility billing analysis or a calibrated whole-building simulation. Whole-building approaches are most appropriate for more extensive retrofits when savings are expected to be 10% or more of total electricity or gas use. Whole-building M&V examines the energy performance at the building level. In addition to their measurement boundary, these methods vary in their requirements for measured data, their application appropriateness, and the level of effort and cost to implement. A summary of the characteristics of each of the four M&V options is presented in Table 5–2.

Credit: RMI

Retrofit-Isolation
Measurement Boundary

Whole-Building
Measurement Boundary

Figure 5–2 Measurement boundary for M&V options

Table 5–2 Overview of IPMVP Options

Method	Option A	Option B	Option C	Option D
Boundary	Retrofit isolation	Retrofit isolation	Whole building	Whole building
Measured data	Key parameters	All parameters	Utility bills	Utility bills, end use, system, equipment
Analysis	Engineering calculations	Regression analysis	Regression analysis	Calibrated simulation
Applications	Limited variation of some parameters impacting EEM savings	Individual EEM assessment	Estimated savings > 10% of total, existing building projects, interacting EEMs	Estimated savings > 10% of total use, interacting EEMs

Credit: RMI

The appropriateness of the M&V approach varies from project to project. Larger projects with larger savings can justify higher M&V expenses and more rigorous methods. Projects with a few EEMs, or EEMs with little interaction may opt for a retrofit isolation approach instead of evaluating whole-building impacts. Utility data analysis using Option C can be a simple method for buildings undergoing retrofits when the energy use is stable and has a strong correlation to weather. Alternately, projects that have developed a detailed energy simulation model as a part of the retrofit evaluation process may be best suited to use Option D.

It is also important to realize that the M&V for a project may include several verification methods. EEMs with little impact, uncertainty, or variation in performance may require a less rigorous M&V approach. Low-cost or no-cost EEMs may rely solely on OV methods that identify their potential to save energy. If a retrofit isolation approach is chosen, some EEMs within the project might follow Option A and others Option B. A project that uses Option C to determine whole-building savings with utility billing analysis might be supported with submetering and trending activities of individual retrofits to ensure all systems perform as expected and savings are realized. If Option C savings fall below their anticipated level, trending from individual retrofits and/or Option B activities can help identify performance issues. For large projects following Option D, calibration might be supported with submetering and conducted at the utility, electric end-use and equipment level. However, smaller projects may calibrate only at the utility energy-use level.

The IPMVP puts forward several general requirements to ensure the adequacy of an M&V effort. These include:

- Developing a complete M&V plan
- Measuring baseline energy use for all operating modes of the building or systems
- Adjusting energy use to the same set of conditions before calculating savings
- Reporting savings only for the post-installation measurement period, and not extrapolating beyond this period
- Establishing the acceptable savings accuracy during the M&V planning process.

5.3 Developing the Plan

An effective verification effort must be planned in advance by developing a detailed M&V plan during the project planning phase. Each project must establish its own specific M&V plan that outlines all activities that will be conducted. The M&V plan should address the project's unique characteristics and be crafted to balance the cost of M&V with the value it provides.

Adherence to the IPMVP requires preparation of a project-specific M&V Plan that is consistent with IPMVP terminology. It must name the IPMVP option(s); metering, monitoring, and analysis methods to be used; quality assurance procedures to be followed; and person(s) responsible for the M&V. Key components of the M&V Plan are outlined in Table 5–3.

Table 5–3 Components of an M&V Plan

Basic M&V Plan Components	
Project description	• Relevant site characteristics • Measurement boundary and metering requirements • Details and data of baseline conditions
Project savings and costs	• A description of the EEMs and performance expectations • Estimated energy and cost savings • All relevant utility rates • Expected M&V cost and accuracy
Scheduling	• Schedule for obtaining baseline information • Schedule for all post-installation M&V activities
Reporting	• All assumptions and sources of data • Identification of deviations from expected conditions • Delineation of post-retrofit period • Documentation of the design intent of the EEMs • Calculation method to be used (all equations shown)
M&V approach	• Selected option(s) (A, B, C, D) • Details on approach for baseline adjustments • Savings calculation details • Operational verification strategies • Responsibilities for M&V activities and reporting • Content and format of M&V reports • Quality control/quality assurance procedures

Credit: RMI

Goals and Objectives

The first step in developing the M&V Plan is to identify the goals and objectives for the M&V activities. The value that M&V provides and costs that can be justified vary based on a project's objectives. For example, M&V cost savings used to determine payments within an Energy Saving Performance Contract will need to be more rigorous than an M&V effort conducted to meet LEED Certification requirements. In many projects, there may be other uses for the M&V equipment and activities, such as tenant submetering or continuous optimization of building or system energy performance, which can help offset costs.

Verification activities can overlap with other project efforts (commissioning, energy modeling, or installation of energy information systems). If the commissioning agent is developing an Owner's Project Requirements (OPR), the M&V goals and objectives should also be stated in the OPR. Inclusion in the OPR will promote a coordinated team approach early on, which promotes leveraging complementary or overlapping efforts.

Determining the Best Approach

The basic purpose of M&V is to ensure the predicted energy savings are realized. Not achieving expected energy savings may be due to inadequate M&V methods, faulty engineering assumptions or analysis, uncertainty introduced from sampling or meter accuracy, or from EEMs being disabled (e.g. overriding controls or VSDs). The M&V approach needs to be sufficiently adequate without being overly expensive. In general, the cost for verification should not exceed about 10% of the annual savings from a project. Using this cost cap as a rule of thumb can help bound the verification activities. In general, the cost for M&V increases with the accuracy of the savings determination, which is impacted by the M&V approach specified as well as the number of metering points, metering duration, measurement sample size, and analysis requirements.

SV plans may call for a single whole-building approach addressing all EEMs for the project, or several M&V options to jointly cover the different measures of the project. Before deciding on the M&V options to use, an assessment must be made of how a specific option will meet the project's goals and constraints, address savings risk, and fall within an acceptable budget. The cost of using a proposed M&V approach must be determined and compared to the risk of not accurately calculating savings. If the project's goals and savings risk do not justify the M&V expenses, the selection of the M&V approach should be reconsidered. All M&V plans should include OV activities for all measures. For low-cost and no-cost measures that have lower savings impacts, including SV activities may not be warranted.

The M&V plan specifies required measurements, time period for data collection, data analysis procedures, algorithms, assumptions, and reporting requirements. Additionally, the M&V plan should include documentation of current and expected comfort conditions, lighting intensities, temperature set points, and similar parameters. These details are critical to understanding the baseline conditions as well as the expected performance of each EEM. Documentation of relevant baseline data may also include equipment specifications, energy use, loads, and hours of operation.

Plan for Ongoing Monitoring

To realize the full value of the retrofit, ongoing verification activities should be included as part of the M&V plan. Some EEMs can be overridden or disabled, so ongoing M&V activities will help to ensure savings persist for the life of the equipment. With this in mind, the team should specify periodic performance verification activities. This effort may be composed of OV activities or a combination of OV and SV activities. Ongoing M&V activities may overlap with performance tracking efforts or ongoing commissioning activities (see Section 6 for more discussion of O&M). Often, these efforts can be combined and may be automated into the building automation system (BAS) or into an energy information system, or fault detection and diagnosis system.

5.4 Recommendations for Specific Measures

Effective M&V methods appropriate for the EEMs discussed in Sections 3 and 4 are listed in Table 5–4. Included for each measure are cost savings impact, performance variability, OV activities, SV activities, and suggestions for ongoing performance assurance. The methods listed are illustrative in the context of the example building and should not be broadly applied to other projects because the nature and scope of the EEMs installed may vary. Further explanation of the methods used to develop the recommended M&V protocols is provided in the following sections.

Table 5–4 M&V Measures for Common EBCx (Tier 1) and Retrofit (Tier 2) Improvements

Tier	Description	EEM Information		Operational Verification Activities	Savings Verification Approach	Savings Verification Activities	Ongoing Performance Assurance
		Savings Impact	Performance Variability				
1	Repair/replace gaskets and seals on refrigerated cases	Low	Low	Visual inspection	None	None	Regular maintenance
1	Verify or establish an effective maintenance protocol for the refrigeration system, and for cooking equipment in kitchen areas and break rooms, including cleaning evaporator and condenser coils, exhaust vents, and burners	Low	Low	Verify implementation of procedures	None	None	Verify implementation of procedures
1	Adjust light levels to within 10% of the IES recommendations for the tasks conducted in each area by delamping and/or relamping	Low	Low	Sample spot measurement	Option A–Partially measured Retrofit isolation	Measure wattages, estimate run hours	Visual inspection
1	Ensure that airflows in refrigerated cases are not blocked by improperly stocked shelves	Low	Low	Visual inspection	None	None	Regular maintenance
1	Apply standby mode to registers when not in use, turn registers off when store is closed	Low	Low	Sample spot measurement	Option A–Partially measured retrofit isolation	Measure wattages, estimate run hours	Visual inspection
1	Disable circulation pumps when building is unoccupied	Low	Low	Visual inspection	Option A–Partially measured retrofit isolation	Measure wattages, estimate run hours	Visual inspection
1	Increase thermostat setback/setup when building is unoccupied	Low	Low	BAS control logic and/or data trending and review	Whole-building approach	Utility data analysis or building simulation	BAS control logic and/or data trending and review
1	Optimize equipment staging/sequence of operation	Medium	Medium	BAS control logic and/or data trending and review	Option B - Fully measured retrofit isolation	Measure wattage over time	BAS control logic and/or data trending and review
1	Test and adjust ventilation flow rates as needed to meet local code requirements	Low	Low	Verify existence of test reports	None	None	Regular maintenance
2	Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts	Medium	Low	Sample spot measurement	Option A–Partially measured retrofit isolation	Measure wattage, estimate run hours	Visual inspection

Table 5–4 M&V Measures for Common EBCx (Tier 1) and Retrofit (Tier 2) Improvements (cont'd.)

Tier	Description	EEM Information		Operational Verification Activities	Savings Verification Approach	Savings Verification Activities	Ongoing Performance Assurance
		Savings Impact	Performance Variability				
2	Replace refrigerated display case lighting with LED	Medium	Low	Sample spot measurement	Option A–Partially measured retrofit isolation	Measure wattage, estimate run hours	Visual inspection
2	(A) Install wireless motion sensors for lighting in rooms that are used intermittently (break rooms, storage areas), and (B) for lighting in refrigerated display cases (B must be bundled with GR-ED-03)	Medium	Medium	Sample spot measurement	Option B–Fully measured retrofit isolation	Measure wattage over time	Visual inspection
2	Install doors on open refrigerated cases	High	Medium	Visual inspection	Option B–Fully measured retrofit isolation	Measure wattage over time	Visual inspection
2	Install compressor unloaders for capacity control	Medium	Medium	Short-term testing	Whole-building approach	Utility data analysis or building simulation	BAS control logic and/or data trending and review
2	Replace standard furnace with a high-efficiency condensing furnace	Medium	Medium	Visual inspection	Option A–Partially measured retrofit isolation	Measure wattage, estimate run hours	Regular maintenance
2	Upgrade to DCV to reduce outdoor airflow during partial occupancy	Medium	Medium	BAS control logic and/or data trending and review	Whole-building approach	Utility data analysis or building simulation	BAS control logic and/or data trending and review
2	Replace inefficient motors with right-sized NEMA premium efficiency	Low	Low	Visual inspection	Option A–Partially measured retrofit isolation	Measure wattages, estimate run hours	Regular maintenance
2	Add high albedo/reflective roof covering (hot climates only)	Low	Low	Visual inspection	Whole-building approach	Utility data analysis or building simulation	Visual inspection
2	Replace lighting system with a more efficient approach (reduced ambient light, greater use of accent lighting, indirect T-5 fixtures in place of direct T-12 fixtures)	Medium	Medium	Sample spot measurement	Option B–Fully measured retrofit isolation	Measure wattages and run hours	Regular maintenance
2	Replace standard low-temperature reach-in and coffin cases with more efficient doored reach-in cases	Medium	Medium	Sample spot measurement	Whole-building approach	Utility data analysis or building simulation	Regular maintenance
2	Add rigid insulating sheathing to roof assembly	Low	Low	Visual inspection	Whole-building approach	Utility data analysis or Building simulation	

Table 5–4 M&V Measures for Common EBCx (Tier 1) and Retrofit (Tier 2) Improvements (cont'd.)

Tier	Description	EEM Information		Operational Verification Activities	Savings Verification Approach	Savings Verification Activities	Ongoing Performance Assurance
		Savings Impact	Performance Variability				
2	Supplement direct expansion (DX) cooling system with an indirect evaporative cooler sized to meet small and medium cooling loads (in dry climates only)	Medium	Medium	Visual inspection	Option B–Fully measured retrofit isolation	Measure wattage over time	Regular maintenance
2	Install DOAS with high-efficiency heat recovery, reducing the heating, cooling, and dehumidification loads	Medium	Medium	BAS control logic and/or data trending and review	Whole-building approach	Utility data analysis or building simulation	Regular maintenance
2	Replace air-cooled heat pump with a right-sized ground source heat pump	Medium	Medium	BAS control logic and/or data trending and review	Whole-building approach	Utility data analysis or building simulation	Regular maintenance
2	Install make-up air units and heat recovery system for kitchen exhaust hoods	Medium	Medium	Visual inspection	Whole-building approach	Utility data analysis or building simulation	Regular maintenance
2	Install high-efficiency condensing water heater	Medium	Medium	Visual inspection	Option B–Fully measured retrofit isolation	Measure wattage over time	Regular maintenance

Measure Characterization

Before the verification approach and supporting activities were specified, the characteristics of the individual EEMs as well as the overall package were considered. As previously discussed, the ultimate aim of M&V is to effectively balance the risk of losing savings against the cost needed to verify them. This risk is tied to the amount of anticipated energy cost savings as well as the performance variability of the measures.

- Energy cost savings impact has been defined as low (0%–1%), medium (1%–3%), and high (>3%) based on the overall retrofit cost savings.
- Performance variability has been defined as low, medium, and high, and is based on level of variability in the performance of the EEM, which may be influenced by hours of operation, user interaction, control sequences, or part-load performance. This criterion defines the likelihood of savings varying from expectations due to performance-related assumptions being different from actual. The performance of certain EEMs, such as envelope improvements, is static and should be as anticipated if properly installed. These EEMs are ranked as low. EEMs that could vary in performance due to differences in operating hours or efficiency, but not likely both, are ranked as medium. These EEMs include automated measures that could be disabled or changed, such as adjustments to control set points. EEMs that could involve a wide range of efficiency with associated operating hours, such as VSDs, are ranked as high.

Operational Verification

OV should be performed as part of any project M&V program. It serves as a low-cost initial step for realizing savings potential and should precede SV activities. A range of OV methods can be applied, as outlined in Table 5–5. Selection of a given approach depends on the EEM's characteristics. However, it can also be influenced by the SV approach taken. For example, if Option B is being used to verify savings, a more simple visual inspection may suffice for OV. However, if Option A is applied, short-term testing might be conducted so that the EEM's performance characterization is complete.

Table 5–5 OV Approach and Application

OV Approach	Typical EEM Application	Activities
Visual inspection	EEM will perform as anticipated when properly installed; direct measurement of EEM performance is not possible. Examples: wall insulation, windows	View and verify the physical installation of the EEM
Sample spot measurements	Achieved EEM performance can vary from published data based on installation details or component load. Examples: fixtures/lamps/ballasts, fans, pumps	Measure single or multiple key energy use parameters for a representative sample of the EEM installations
Short-term testing	EEM performance may vary depending on actual load, controls, and/or interoperability of components. Examples: Daylighting sensors and lighting dimming controls, VSD fans, DCV.	Test for functionality and proper control. Measure key energy-use parameters. May involve conducting tests designed to capture the component operating over its full range or performance data collection over sufficient period of time to characterize the full range of operation.
BAS control logic and/or data trending and review	EEM performance may vary depending on actual load and controls. Component or system is being monitored and controlled through the BAS.	Set up and review BAS data trends and/or BAS control logic. Measurement period may last for a few days to a few weeks, depending on the period needed to capture the full range of performance.

Savings Verification

Including an SV component as part of the project M&V is critical for some applications (e.g., energy savings performance contracts or LEED 2009 Design & Construction Energy & Atmosphere Credit 5 adherence). For small projects and EEMs with little savings potential or variability, only the simplest SV methods may be justified. Typically, SV is not conducted for maintenance-type measures or EEMs with small savings, especially those that are challenging to measure or where it is difficult to define their baselines.

Retrofit isolation approach

Option A Retrofit isolation approach is less rigorous than Option B and is applied to measures that have low savings and low performance variability. Post-installation, either performance (e.g., wattage) or operation (e.g., operating hours) is measured. The value for the nonmeasured parameter is estimated or based on baseline measurements. Grocery store EEMs that would use an Option A SV approach include those involving equipment replacements that maintain the same operating schedule, such as appliance replacement, furnace replacement, refrigerated case replacement, and on/off lighting system replacement.

Option B Retrofit isolation approach fully characterizes the post-install EEM by measuring all energy use parameters (e.g., wattage and operating hours). It is most appropriate for EEMs with higher savings and/or higher performance/operating variability. Grocery store EEMs assigned an Option B savings verification approach include those involving equipment change outs accompanied by changes in controls or part-load performance, such as active daylighting controls and refrigeration system improvements.

Whole-building approach

A whole-building SV approach is most appropriate for projects that include interactive EEMs or those for which performance improvements are challenging to directly measure. If a whole-building approach is followed, the retrofit isolation methods are generally not implemented but might be conducted for select measures to verify savings at the EEM level. When relying on a whole-building approach, it is critical to include a strong OV component, including ongoing, data-driven activities.

Option C Utility billing analysis is generally selected as the whole-building approach for projects where the energy cost savings are not large enough to justify the higher costs associated with implementing Option D.

Option D Whole-building calibrated simulation analysis can be justified if the project savings are high and results from the simulation can be used to evaluate and inform the building's optimized performance.

Approach for Retrofit Packages

The M&V approach for the three tiers should include an OV component. This will ensure that energy efficiency improvements are installed and have the potential to save energy. Because of the relatively low savings associated with a Tier-1 type package, the M&V will probably not include an SV component due to the added expense. Of course, rough savings calculations can be made to see if estimates are close to expectations, but the methods will not be considered to be IPMVP adherent.

For grocery store projects able to justify spending $5,000 or more on M&V (corresponding to at least $50,000 estimated savings), SV can be determined by following either a retrofit isolation approach (Options A and B) or a whole-building Option C approach. Projects with less savings/smaller M&V budget will need to be more targeted in their efforts. For example, these projects can focus on the EEMs that have higher impact and/or more variable performance. It is also possible to follow Option C but also include Option A and Option B on select EEMs and/or a strong OV component, but in most cases Option C is not mixed with Option A and Option B for end uses on the same utility meter. Supplementing Option C with additional M&V efforts may be particularly warranted if Option C reveals lower savings than anticipated. If Option C is the primary method selected for verifying savings, ongoing performance monitoring should occur during the M&V period.

For grocery store projects able to justify spending at least $15,000 on M&V (at least $150,000 in savings), SV might be determined through an Option D approach. This approach is most feasible if an energy model of the project already exists and is available to support M&V. The benefit of using Option D instead of Option C is that one is able to compare expected and actual performance for major building end-uses and systems. These comparisons can reveal discrepancies between modeling assumptions and reality. They can also reveal shortcomings in actual operation that can be rectified for improved performance.

Persistence

Performance assurance activities are conducted to ensure EEM savings persist once the M&V period has passed. These activities follow the same categories as those described for OV.

5.5 Additional Resources

Use these resources for more detailed information about M&V best practices for existing buildings:

The International Performance Measurement and Verification Protocol (IPMVP) is available at *www.evo_world.org*. (EVO 2010)

The Building Performance Tracking Handbook was developed by PECI for the California Energy Commission (CEC 2011). *www.cacx.org/PIER/documents/bpt-handbook.pdf*

California Commissioning Collaborative, "Building Performance Tracking Handbook," 2011: Includes a discussion of performance tracking tools relevant to M&V activities. Available for free download online. *www.cacx.org*

DOE, "M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0," 2008: Guidelines and methods for measuring and verifying energy, water, and cost savings associated with federal energy savings performance contracts (ESPCs); much of the content is relevant to M&V activities in private sector buildings. Available for free download online; *www.eere.energy.gov*.

ASHRAE, "Guideline 14," 2008: A standard set of energy (and demand) savings calculation procedures for M&V activities. More information available at *www.ashrae.org*.

6 Continuous Improvement Through Operations and Maintenance

6.1 What Is Operations and Maintenance?

O&M is the combination of mental (operations) and physical (maintenance) activities that are required to keep a building and its energy systems functioning at peak performance. Operations focus on the control and performance optimization of equipment, systems, and assemblies. Proper operations help ensure that equipment produces the required capacity when needed, and that it produces this capacity efficiently. Maintenance typically refers to routine, periodic physical activities conducted to prevent the failure or decline of building equipment and assemblies. Proper physical care helps ensure that equipment maintains its required capacity and that assemblies maintain their integrity. O&M is an activity that almost all facility management staff engages in, but the nature of that engagement varies. Some engage in reactive O&M, primarily responding to complaints and breakdowns; those with a well-planned comprehensive O&M program work proactively to prevent complaints and failures.

Implementing a comprehensive O&M program with limited resources is a common challenge. All too often, a lack of funding, time, manpower, or even training prevents holistic and optimized O&M. Dedicating the resources can be advantageous, though, as a well-run O&M program can achieve the following (DOE 2010):

- Whole-building energy savings of 5%–20%
- Minimal comfort complaints
- Equipment that operates adequately until the end of its planned useful life, or beyond
- Design levels of indoor environmental quality
- Safe working conditions for building operating staff.

Optimizing a building's O&M program is one of the most cost-effective approaches to ensure reliability and energy efficiency, as a building's O&M practices can often be significantly enhanced with only minor initial investments (DOE 2010).

When planning for energy upgrades, a building owner needs to evaluate how each retrofit will impact the O&M program, and if current O&M practices are adequate. Additional training or resources may be required to maintain the systems and/or assemblies affected by the upgrade, or to maintain the benefits associated with the upgrade. For more modest retrofits, the O&M program may not be affected, as these retrofits usually replace systems and components with similar but more efficient systems and components. However, even in these instances it is important to evaluate the sufficiency of the current O&M program and consider devoting additional planning and resources to maintain the performance and benefits of these retrofits.

6.2 Management System

Successful O&M practices require the support and coordination of much more than just the operations staff. Integration across all levels of an organization is vital to empowering the right people at the right time to produce and sustain an energy efficient building. Five key elements of a management system capable of producing a comprehensive and optimized O&M strategy are represented by the acronym "OMETA" (Operations, Maintenance, Engineering Support, Training and Administration) (Meador 1995).

- **Operations.** Effective operations plans and protocols to maximize building system efficiency
- **Maintenance.** Effective maintenance plans and protocols to maximize building system efficiency
- **Engineering support.** Availability of technical personnel who can effectively carry out an O&M program
- **Training.** Adequate training facilities, equipment, and materials to develop and improve the knowledge and skills necessary to perform assigned job functions
- **Administration.** Effective establishment and implementation of policies and planning related to O&M activities.

OMETA describes the key elements of O&M management. It is also vital to establish a clear framework for communication and cooperation among the various groups included in an O&M management structure. For a retail building, these groups can include:

- Property manager or owner's representative
- In-house operations staff
- Service contractors
- Energy managers
- Building occupants.

An individual responsible for maintaining the lines of communication between the various groups, referred to as an in-house champion, is a critical part of this framework. This champion must be knowledgeable about the building systems and involved in decision making related to operations. The role of champion is vital to the O&M process, as lack of support from any element of the structure can greatly reduce the benefits of O&M and limit the ability to achieve and retain a fully optimized building.

When implementing the EBCx process or retrofits in a building, it is important to obtain buy-in from all parties associated with an O&M program. Buy-in from all parties will result in maximizing the persistence of benefits related to the upgrade. The O&M team needs to be closely involved in all core building-related upgrades, as will it maintain the systems and assemblies and ultimately define the sustainability of upgrades.

An additional O&M management consideration is how O&M can be affected if a building outsources O&M responsibilities to a maintenance management firm, as is often the case with retail buildings. These firms are often highly skilled and capable of implementing advanced O&M programs, but will only do so if it is specified in the service agreement. Building owners can review their service agreements and talk to their service providers to determine what level of O&M activity is currently contracted and what may be lacking. When entering into a new service agreement, building owners are encouraged to seek out vendors that offer comprehensive O&M.

6.3 Program Development

> Haggen, Inc. is the largest independent grocer in the Northwest, with 33 stores throughout Washington and Oregon. Haggen managers decided to participate in the ***EnergySmart Program***, an incentivized program designed to help participants reduce their energy use. By addressing relatively simple items that a standard grocer O&M program should cover, such as refrigeration door gaskets, refrigeration motors and strip curtains, Haggen was able to save approximately $300,000 annually in energy costs across the 24 participating stores by eliminating the use of more than 2.5 million kWh (EnergySmart 2009).

Implementing an O&M program serves a crucial role in an energy upgrade—upgrades provide an initial efficiency boost, and a good O&M program will make sure that the savings persist. All building systems degrade over time—light output decreases through natural lumen depreciation and dirt buildup; control systems drift from set points or occupants override or disable the optimum settings, heat exchangers become fouled, motors and drives wear out, and dozens of other problems can arise.

A good O&M program anticipates all the expected degradations, and monitors building status to catch the unexpected as well. The action items can be proactive, such as prescheduled preventative maintenance plans, and reactive, responding to problems as they arise.

For an O&M program to be successful, planners and participants must understand all of the building systems and equipment and how they are operated and maintained. Most building systems interact with each other, so if one is operating inefficiently, others may follow suit. For example, if a building's lighting system is providing more light than necessary, the HVAC system will have to compensate for the additional heat added. These kinds of interactions can be hard to detect without a comprehensive approach to O&M.

Developing an Effective Plan

Successful O&M starts with the energy upgrade plan—O&M is easier if it is planned for in advance. A good program also requires defining and communicating the goals, and identifying partners who may either participate in, or contribute to, the program.

Design for Maintenance. The best results come about when maintenance is addressed from the start of the energy upgrade process. For example, a lighting upgrade can include components that minimize lumen degradation, offer long lamp life, and minimize the number of different lamp types that must be stocked. If upgraded HVAC or refrigeration equipment is different in shape or size from existing equipment, designers should make sure that there is still easy access for cleaning coils and filters. Coils and air filters should be selected to minimize maintenance costs in the expected environment—dry versus humid, clean air versus dirty, and other factors.

Goals. O&M program goals are to maintain the improved operational efficiency of building systems. Normal equipment degradation and building occupant adjustments can quickly deteriorate benefits after an upgrade. O&M goals will guide building staff as they develop regularly scheduled maintenance activities to actively monitor building systems.

Communication. An O&M program will be most successful if all parties are informed of the goals and expected benefits—from ownership, corporate, and store management all the way down to the employees and store's shoppers. It's also important to emphasize that savings might not be realized immediately but will accrue over time. Effective O&M programs generally have payback periods of less than 2 years, and communicating this fact early on is a key to the program's success (PNNL 2010).

Engage Partners. Selecting the right team members for an O&M program increases its effectiveness. The owner, facility manager, building maintenance staff, and any other parties involved in the operations of a grocery store or supermarket should be represented. Staff members with extensive knowledge of the building and its systems can add tremendous value to both determining the objectives of the program and the implementation schedules.

The participation of other parties outside the store often helps, particularly if staff members lack the expertise or time to carry out all aspects of the O&M program. Contact local utilities early in the process to see what options are available for obtaining energy use data in the most useful format. Sometimes utilities can offer technical assistance with issues that arise during O&M implementation, such as interpreting submetered data and peak shaving. External consultants with O&M program experience can help stores set up, implement and manage an O&M program. Facility managers and O&M staff can also look outside their own store or portfolio of stores to find other grocers with active O&M programs and learn from their experiences. The *EnergySmart Program* and the *Better Bricks for Grocers* program both offer resources such as case studies and best practices that can assist grocers interested in developing an O&M program. Another option for grocers is the *Retailer Energy Alliance*, a DOE collaborative group of retail stores, including Whole Foods Market, Inc., and SUPERVALU, Inc., focused on energy-efficient design and operation of retail facilities.

Training

Once the goals and purpose of the program are defined, building staff and store management will need training on changes, upgrades, and system improvements. A training and overview session with building staff will ensure that they are up to speed and ready to initiate the O&M program.

Management teams and building staff need training on how to maintain optimum building operations after the upgrade. For major projects, the new systems will go through a commissioning process; and the commissioning agent should also provide operator training. A hands-on workshop is an effective way of teaching staff members how to properly maintain and operate building equipment. Covering topics such as energy use and expected improvements ties operations together with maintenance. Consider recording these training sessions as a resource for future training sessions. All employees must also be educated to understand how their actions impact the O&M program. Their contributions made during daily activities within the store are an important aspect of the overall success.

Recommissioning

Recommissioning can serve as the foundation of a good O&M program. An effective grocery store upgrade begins with a retrocommissioning effort that identifies areas where lighting, refrigeration, and HVAC systems are not operating as planned. O&M programs identify low- and no-cost ways to maintain changes made as part of the retrocommissioning effort. A recommissioning effort will detect and correct any major systemic problems that develop over time, and ensure that savings persist. Timing for the recommissioning will vary, but every three to five years is a typical recommendation. If utility bills are higher than expected or O&M staff is constantly repairing the same equipment, it might be time to consider recommissioning. Retro- and recommissioning yield average whole-building energy savings of 16% and a simple payback of 1.1 years, according to Mills (2009).

Ongoing commissioning can sometimes be a cost-effective approach as well. Monitoring equipment is installed to gather ongoing diagnostic information and signal when actions are required. This approach works best in stores with a modern EMS, and where there is an individual committed to the energy upgrade process. An up-to-date EMS provides a wide range of control strategies and usually tracks most of the data needed for diagnostics.

Good Operations and Maintenance Practices

The O&M program covers overall systems and building policies as well as specific areas including lighting, HVAC, water heating, and miscellaneous systems.

Overall systems and policies

A good O&M program starts with collecting and creating O&M resource documents. It also covers a BAS or an EMS when present, and includes an O&M friendly purchasing policy.

Reference material. O&M staffs rely on equipment lists and reference manuals for the information they need to operate and maintain building systems and equipment. The upgrade process provides stores the opportunity to evaluate the status of O&M documentation and update or create new references as needed. Equipment lists provide basic information about each piece of equipment.

- Manufacturer's name
- Name plate information
- Unique name/number (if necessary)
- Vendor's name
- Installation date
- Location within the building.

Reference manuals should also be on file for all building systems. These manuals could be equipment manuals from the manufacturers or system control documents explaining the new set points and operation sequences in place after the upgrade. The U.S. Department of Health and Human Services provides a blank template that O&M staff can fill in for each building system and piece of equipment (HHS 2011). The template supplies sections for system descriptions, usages, and maintenance, among other items. O&M staff can use these sections to find all the information necessary for a reference manual. O&M staff should also keep an open journal or log for each piece of equipment or building system to chronicle all maintenance activities.

BAS. When introducing a new O&M program, take advantage of any BAS or EMS that might be in place. One survey of 11 buildings with BASs in New England found that five of the buildings were not fully utilizing their BASs, achieving only 55% of expected savings. Furthermore, one building realized no savings at all because operators never implemented the intended BAS control strategies correctly (Wortman et al. 1996). A BAS comprises automated systems, which can be programmed to control setbacks, shutdowns, and startups, as well as other energy-saving actions. Some EMS or BAS have automated diagnostic capabilities to alert O&M staff of impending operational issues or other problems that are difficult for staff to diagnose. They can also collect performance data that can be further analyzed for operational performance evaluation and benchmarking purposes. These systems can be costly and require intensive training for the staff, but when properly used, they become a valuable tool for increasing a building's efficiency.

Purchasing Policy. Using inefficient replacement parts can undermine energy-saving efforts. A purchasing policy that emphasizes efficiency can ensure that only the most efficient options are used. For example, if a building upgrade includes the installation of high-performance T-8 lamps, the purchasing policy should ensure that only those lamps are in stock—that way if an employee reports a lamp burnout in the store, only the efficient version will be available to replace it.

The policy should also consider maintenance requirements for each item. Procurement staff should evaluate maintenance records and useful life of potential items and stock only those with proven track records. Procurement plans can decrease repair and replacement times by requiring the purchase of efficient items that need little to no maintenance. For example, purchasing air filters with three months of useful life that offer equivalent performance to filters with only one month of useful life will provide O&M staff additional time for other priorities.

The EPA and DOE's Federal Energy Management Program (FEMP) provides purchasing and procurement resources that can help organizations find energy-efficient products. These resources include lists of qualifying products, key product criteria, drop-in procurement language, and savings calculators. See the EPA list of *ENERGY STAR products* and visit the *FEMP website* for products not covered under the ENERGY STAR program.

Lighting

Lighting systems lose efficiency over time. Some of these losses are inevitable—light sources naturally degrade as they age. But other efficiency losses—dirt accumulation on fixture lenses, reflectors, and lamps; or controls drifting out of calibration, can be avoided by regularly scheduled maintenance.

Cleaning. Lighting levels can decrease by as much as 15% without proper cleaning. Cleaning dirt and dust off lamps and their covers keeps light output at the maximum level. Lighting covers and diffusers darken with age and will eventually need replacement, but regular cleaning should extend their useful life. Cleaning is most effective when built in with another O&M program, such as group relamping.

Check light levels. Once lights have been replaced and cleaned, measure the existing lighting levels to determine if they are appropriate for the tasks performed in that space, and ensure that products are properly lit. Overlit and underlit areas should be adjusted to provide appropriate light levels.

Group relamping. A planned group relamping program is typically more cost effective than spot replacing burnouts. With group relamping, a number of lamps are replaced at the same time—usually at 60%–80% of rated lamp life. This process usually results in higher lamp costs, which may be more than offset by lower labor costs. Stores will also enjoy brighter and more uniform lighting because all lamps will be replaced at similar points in the degradation process, before their output fully degrades. Another benefit is that additional lighting O&M activities can be coordinated with the relamping process, including cleaning and ballast inspection.

Controls. Inspect lighting control systems regularly to ensure that lights are off when spaces are unoccupied or to take advantage of daylighting opportunities. Evaluate and adjust automatic timers as needed and push the start time back as late as possible. Nighttime and outdoor lighting should be minimized as much as safety and local ordinances allow. Controls and sensors for other systems, including temperature and pressure sensors for HVAC and refrigeration, should also be calibrated at the same time. If an EMS system is present, the programming and operation should be verified and optimized consistent with the current operating schedule of the store.

Refrigeration

Refrigeration is the largest energy consumer for the average grocery store, accounting for almost half the energy use. Regular maintenance should keep these systems online and operating efficiently.

Display case doors. Proper door operation and sealing is one of the most important maintenance items due to the wear and tear these doors experience. Keep all door gaskets clean and functional and replace any worn gaskets immediately. Inspect doors for smooth opening and closing and ensure that all seals are engaged when doors are closed.

Case temperature settings. If temperature settings in refrigerated systems drift too low, the cases will use more energy than necessary. The most commonly used settings for freezers are between –14°F and –8°F. For refrigerators, they are between 35°F and 38°F.

Unit coolers. Inspect all units for signs of leaks or corrosion. O&M staff should confirm that drain pans are free of residues and ice buildup and that units are draining properly. O&M staff should also address any excessive noise or vibration within the units.

Cooling equipment. Refrigerant charge should be checked regularly, as over- and undercharged systems can significantly reduce efficiency. Regular inspections should also help O&M staff identify leaks.

Fans. Cleaning fan blades annually can extend the life of the fan and gives O&M staff the chance to inspect for chips or cracks. Inspect the bearings and lubricate as the manufacturer recommends, usually no longer than 6-month intervals. Examine the belts for wear and appropriate tightness.

Coils. Dirty condenser and evaporator coils reduce air flow and cooling capabilities. Inspect both regularly and clean as necessary.

HVAC

O&M activities for the HVAC system can have a large impact on building efficiency and comfort, considering that heating, cooling, and ventilation typically account for 22% of the energy consumed by grocery stores (DOE 2006).

Furnaces. The operating manual from the furnace manufacturer should provide normal operation guidelines. Other program suggestions include checking for gas leaks regularly, inspecting limit devices and flame sensors and checking the flue for blockage. Installing controls to set back the supply temperatures during unoccupied periods will help save energy as well.

Cooling equipment. Refrigerant charge should be checked regularly, as over- and undercharged systems can significantly reduce efficiency. Regular inspections should also help O&M staff identify leaks.

Air handlers. Airflow rates should be tested every few years to confirm that they meet minimum requirements. Lowering ventilation rates can save energy, but can also decrease IAQ. The right balance will depend on occupancy levels and climate. Desired airflow rates for each system should be stated in the O&M reference documents.

Economizers. Economizers use controlled dampers to automatically open and close as outdoor conditions dictate. By design, they house many moving parts. Cleaning, lubricating, and inspecting these parts regularly, three or four times per year, can keep the dampers from getting stuck in any position.

Coils. Dirty condenser and evaporator coils reduce airflow and cooling capabilities. Inspect both regularly and clean as necessary.

Fans. Cleaning fan blades annually can extend the life of the fan and gives O&M staff the chance to inspect for chips or cracks. Inspect the bearings and lubricate as the manufacturer recommends, usually no longer than 6-month intervals. Examine the belts for wear and appropriate tightness.

Air Filters. Dirty air filters reduce the airflow through the system by blocking airflow. This blockage requires more power from the fan motor to push the air through. Consider using filters with larger cross-sections because they use less energy to move air through the filter. Most filters need to be replaced every 1–3 months as recommended by the manufacturer. O&M staff should inspect filters regularly and replace as needed.

Air Ducts. Air leaks can drastically reduce cooling system efficiencies. O&M staff should inspect all access panels and gaskets for leaks at regular intervals, at least once a year. Inspecting the entire duct system should also be performed regularly, although not as frequently. Look over appropriate areas to ensure that nothing is blocking access panels or air intakes.

Controls. Regular maintenance of control systems is crucial because settings may have been changed by occupants or the systems may be defective or may have drifted out of spec. System settings are determined with energy efficiency in mind and O&M staff should test and verify all systems periodically, particularly those affected by seasonal changes.

Water heating

Although water heating typically accounts for less than 5% of total energy costs for grocers (E Source 2008), losing the hot water system due to equipment malfunction can be crippling to operations. Inspection and evaluation of the water heater and delivery system will prevent energy losses and extend equipment life.

Storage tank insulation. Storage type water heaters can lose efficiency through heat loss from the water stored in the tank. If insulation was added as part of an energy upgrade, check to make sure that the integrity of the insulation is maintained.

Burners. Gas- and oil-fired burners should be tested and adjusted annually to maintain optimum operating efficiency.

Pipe insulation. Hot water delivery pipes, particularly those in unconditioned spaces, should be insulated to optimize the heat delivery process. O&M staff should inspect this insulation regularly because it will deteriorate over time.

Hot water fixtures. Hot water fixtures should be flushed occasionally to control bacteria growth. Water heaters with storage tanks should be flushed out annually to remove any sediment that reduces the system's heat-transfer efficiency.

Reduce water use. Reducing hot water use throughout the store will lessen the load on the water heater. Finding and repairing leaks will also reduce the load on the water heater.

Miscellaneous

The O&M program should also cover a number of other areas, including the building envelope, plug loads, and kitchen equipment.

Building envelope. Eliminate air and water leaks by sealing the building envelope. Inspect doors, windows, roofing, and the foundation for leaks and repair using caulking or weather-stripping. Constant complaints about drafty areas will help O&M staff locate these leaks. Other signs, such as doors not closing and water marks, are indicators of an inefficient envelope.

Plug loads. Plug loads refer to the electricity drawn by any device plugged into a wall outlet. Managing them is vital for the O&M program. Employee participation is necessary because they are most aware of plug loads and have more control in limiting them. Turning computers and monitors off when not in use can save a significant amount of energy. Even setting computers to "hibernate" mode after periods of inactivity will reduce their power draw. Using ENERGY STAR equipment can help reduce plug loads as well. Implementing smart strip surge protectors in equipment-heavy rooms will help eliminate phantom loads, the power drawn by certain appliances even when turned off or in standby mode. Simply unplugging devices when they're not in use can also help reduce energy consumption. LBNL provides a *list of standby power draw* for common plug loads. This can help O&M staff estimate how much standby power is being consumed throughout the building.

Kitchens. Cleaning vents and heating coils will increase the efficiency of kitchen equipment. Consider ENERGY STAR appliances when it comes time to upgrade equipment.

Additional Resources

Use these resources for more detailed information on O&M programs for grocery stores and supermarkets:

Building Upgrade Manual from ENERGY STAR, a strategic guide for energy saving building upgrades. *www.energystar.gov/index.cfm?c=business.bus_upgrade_manual*

Operation and Maintenance Systems – A Best Practice for Energy-Efficient Building Operations from Portland Energy Conservation, Inc., explains where to begin the process of developing an O&M program. *www.energystar.gov/ia/business/assessment.pdf*

Operations & Maintenance Best Practices – A Guide to Achieving Operational Efficiency, Release 3.0 from the Federal Energy Management Program, an extensive resource of best practices and O&M tips for many types of building equipment and systems. *www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf*

A Retrocommissioning Guide for Building Owners from Portland Energy Conservation, Inc., a guide explaining the retrocommissioning process, including a section on maintaining benefits long after the commissioning process is complete. *www.peci.org/documents/EPAguide.pdf*

Cooler Connection is a site completely dedicated to refrigeration systems, walk-in units and display cases for the food service industry. *http://blog.uscooler.com/*

EnergySmart Program is an incentivized program designed to help commercial businesses reduce their energy use. The program offers energy audits, equipment rebates and advice on energy efficiency measures and technologies. *www.energysmartonline.org/index.html*

Retailer Energy Alliance is a DOE collaborative group of retail stores focused on energy-efficient design and operation of retail facilities, including grocery stores. *www1.eere.energy.gov/buildings/alliances/index.html*

Better Bricks is an initiative aimed at improving energy efficiency in commercial buildings managed by NEEA. They have an entire section dedicated to grocery stores and supermarkets. *www.betterbricks.com/grocery-stores/tools-resources*

Building Operator Certification (BOC) courses provide training for building operators to improve their ability to operate and maintain comfortable, efficient facilities. *www.theboc.info/*

Purchasing & Procurement page from ENERGY STAR, a compilation of ENERGY STAR qualified products as well as resources for developing efficient procurement policies. *www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing*

Procuring Energy-Efficient Products page from FEMP, similar to the ENERGY STAR procurement page with more information on procurement policies and energy-efficient product categories outside of ENERGY STAR. *www1.eere.energy.gov/femp/technologies/procuring_eeproducts.html*

BOMA, "Preventive Maintenance: Best Practices to Maintain Efficient & Sustainable Buildings": A comprehensive guide to establishing and implementing a preventive maintenance program. Available for purchase online; *www.boma.org*.

California Commissioning Collaborative, "Building Performance Tracking Handbook," 2011: A guide to utilizing building performance tracking to maximize savings from energy upgrades. Available for free download online. *www.cacx.org*.

PNNL: "Maintaining the solution to Operations and Maintenance efficiency improvement," 1995: defines the key elements of a holistic approach to O&M management: Operations, Maintenance, Engineering Support, Training and Administration (OMETA). Available for free download online. *www.osti.gov/bridge/servlets/purl/87062-g0jJUA/webviewable/*

7 Conclusion

Grocery stores have the second-highest energy cost intensity of all building types, behind only food service buildings, and the highest energy cost intensity for electricity (DOE 2006). We have also demonstrated that existing grocery stores contain ample opportunity for energy saving improvements. This guide demonstrates that significant energy savings is relatively easy to achieve through EBCx, and that much greater savings can be accessible for energy managers and store owners who are willing to invest in deep, holistic retrofit projects. The rigorous financial analysis methods presented in this guide show that the long-term benefits from these retrofits considerably outweigh the costs. Rising energy costs, climate risks, regulatory risks, and growing market value placed on sustainability are other drivers moving building energy upgrades from a niche activity to an essential activity to maintain competitiveness.

When analyzed in the context of a representative grocery store, we were able to identify energy savings ranging from 9.3% for an EBCx package in Miami to 34% for a whole-building retrofit package in Seattle, as shown in Figure 7–1. Energy savings for retrofit packages are independent of EBCx, and the combined package will result in even higher savings, though less than the sum of the two separate packages because the benefit of certain EBCx measures would be consumed by retrofit measures for the same system (such as repairing seals on refrigerated cases before replacing the cases). For reference, the energy savings levels for the 50% grocery store new construction packages developed by NREL are also shown in the graph (Leach et al. 2009). The modeling of retrofits was very conservative for our example building, because many measures appropriate for whole-building retrofits (such as major equipment replacements and enhanced daylighting) were not considered in our analysis, and an integrated design approach that considered the interactions among measures was not applied. Additional savings opportunities are very likely when applied to an actual grocery store, when all retrofit measures are considered, and when available financial incentives are included.

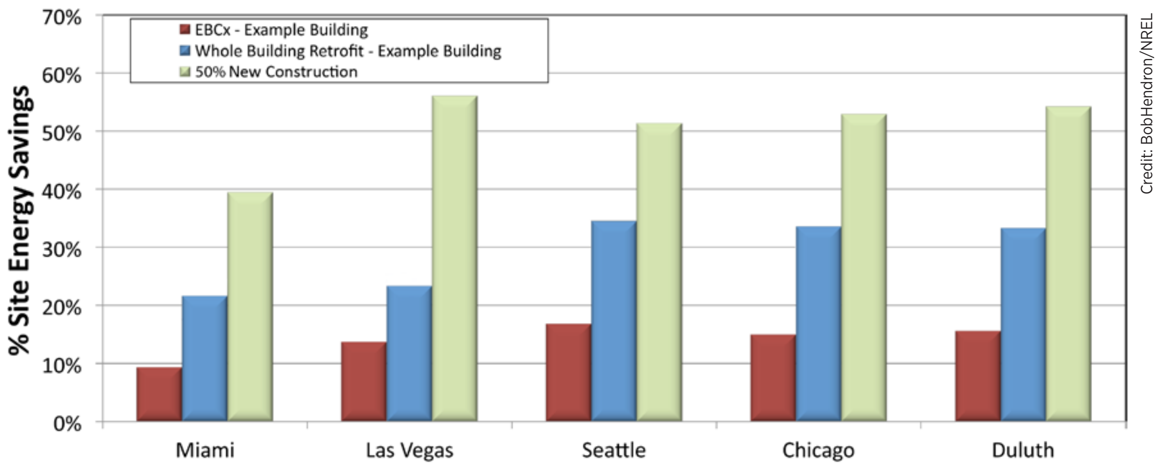

Figure 7–1 Site energy savings for example grocery store

Policymakers may be interested in the source (or primary) energy savings associated with the recommended packages. Source energy includes the energy used on site, along with the energy lost or consumed during the generation, transmission, and distribution process. The source energy multiplier for electricity is about 3.4, and the multiplier for natural gas is about 1.1. The energy savings expressed in terms of source energy are shown in Figure 7–2.

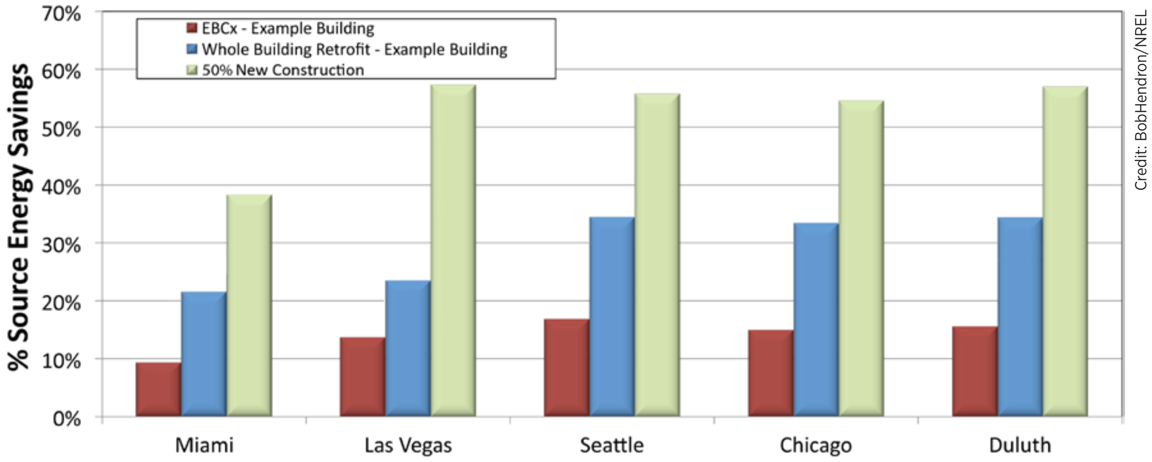

Figure 7–2 Source energy savings for the example grocery store

Although most would agree that improving building performance is the right thing to do, and acknowledge the wide range of options, navigating those options and developing a profitable long-term strategy has been far from easy. This guide breaks down the myriad options into prioritized retrofit measures and recommended packages based on a typical grocery store, providing a strong start for any energy manager. The guide presents cost-effectiveness metrics for each package that recognize the complexity of companies' business processes.

Even the most compelling business case might fall short of success without sound planning and implementation. Therefore, this guide describes proven approaches to project planning and execution. Companies can drive their buildings toward higher performance by setting goals, creating a long-term plan, and carefully tracking progress. The roadmap presented in this guide can help lead building owners from recognition of the opportunity through the full journey that leads to high performance.

A wide array of resources is available to grocery store energy managers that seek to enhance building performance. This guide includes links to a host of other resources that energy managers may wish to consult. With the help of information and assistance offered by many government agencies, utility companies, and other organizations, nearly every energy manager or grocery store owner is within easy reach of an energy savings project.

We hope that this guide will give grocery store energy managers and owners the confidence to take aggressive actions to improve the energy efficiency of their building portfolios, and will prove to be a valuable reference as building improvement projects are implemented.

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Appendix A

Cost-Effectiveness Analysis Methodology

The economic analysis of retrofit measures is one of the most challenging topics to address in a guidebook, yet is absolutely essential for building owners or energy managers trying to develop a convincing business case for a retrofit project. This guide provides clear methodologies for calculating both NPV and simple payback period. We recognize that while NPV is the preferred metric because it better captures the full range of benefits and costs associated with an investment over time, simple payback remains the most commonly used metric for quantifying the cost effectiveness of energy retrofit projects.

In this appendix, we will address the economic analysis of retrofit measures in a much more practical manner than has been attempted in other retrofit guides. We will provide methods for accurately quantifying multiyear cash flows, including energy costs, demand reduction, replacement costs (including reduced energy savings if more efficient equipment would have been required by code), salvage value, O&M costs, and M&V costs. Techniques and references will also be provided for capturing the effects of temporary financial incentives offered by government agencies or utilities (such as rebates, low interest loans, tax credits, etc.) on multiyear cash flows. Although it can be challenging to quantify the cash flows associated with a project, there are many tools available to assist with the calculation of both NPV and simple payback, including the free *LCCAid tool* developed by Rocky Mountain Institute (*www.rmi.org/ModelingTools*).

The recommended methodology described in this guide has been applied to an example grocery store (see Section 1.4 and Appendix B), resulting in the selection of building improvement packages for retrofit projects in five locations. The purpose of the example is to illustrate the economic analysis and measure selection process in the context of a realistic scenario, and to provide the reader with some idea of the energy savings potential of the measures described in this guide. However, it is important to note that certain measures may be highly cost effective in the example building, but may be a very poor choice in a different situation. Age of equipment, cost structure, financing terms, tax incentives, local weather conditions, and system interactions can all have very large impacts on the cost effectiveness of a particular measure.

A.1 Overall Net Present Value Calculation

As discussed in Section 2.6, NPV is the financial analysis metric that best captures the full economic value of a retrofit measure or package of measures from the building owner's perspective, especially when evaluating a staged retrofit. NPV is an integral component of life cycle cost analysis, but we will limit our analysis to direct costs and benefits that impact a grocery store's budget. Societal and environmental costs will not be addressed, except to the extent they are reflected in taxes, financial incentives, purchase costs, and disposal costs.

Equation A–1 provides the general definition of NPV used in this guide:

$$\text{NPV} = C_0 + \sum_{t=1}^{N} \frac{C_t}{(1+DF)^t} \tag{A–1}$$

Where:

- C_0 = initial investment and related cash flows in Year 0
- C_t = sum of cash flows in Year t (current year dollars)
- t = years after initial investment
- N = number of years in analysis period
- DF = real discount factor (does not include inflation)

We recommend a 20-year project analysis period for calculating NPV. This time period is longer than the useful life of most of the measures that will be evaluated, and provides a fair cutoff point for energy savings and other benefits associated with a measure. There is also likely to be major remodeling or other modifications to a building or its use beyond a 20-year timeframe, which would negate the value of many retrofit measures. Finally, cash flows beyond 20 years are significantly discounted in the NPV calculation, and no longer hold much weight in the analysis.

Discount factor is defined as the minimum rate of return required by the building owner, and is usually equal to the return that can be expected from alternative investment opportunities with similar risk. The appropriate discount factor can vary wildly depending on the risk tolerance of the building owner, type of financing, uncertainty in energy savings, and alternative investment options that may be available. Because most grocery stores are privately owned, a relatively high discount factor is usually appropriate. If the required simple payback is known for an organization, the corresponding discount factor can be estimated using the graph in Figure A–1. This correlation was developed by calculating the internal rate of return over a 20 year period for a simple investment in Year 0 followed by a stream of equal positive cash flows consistent with the required payback period. The implied discount factor is the discount factor that when applied to these cash flows, would result in an NPV of zero.

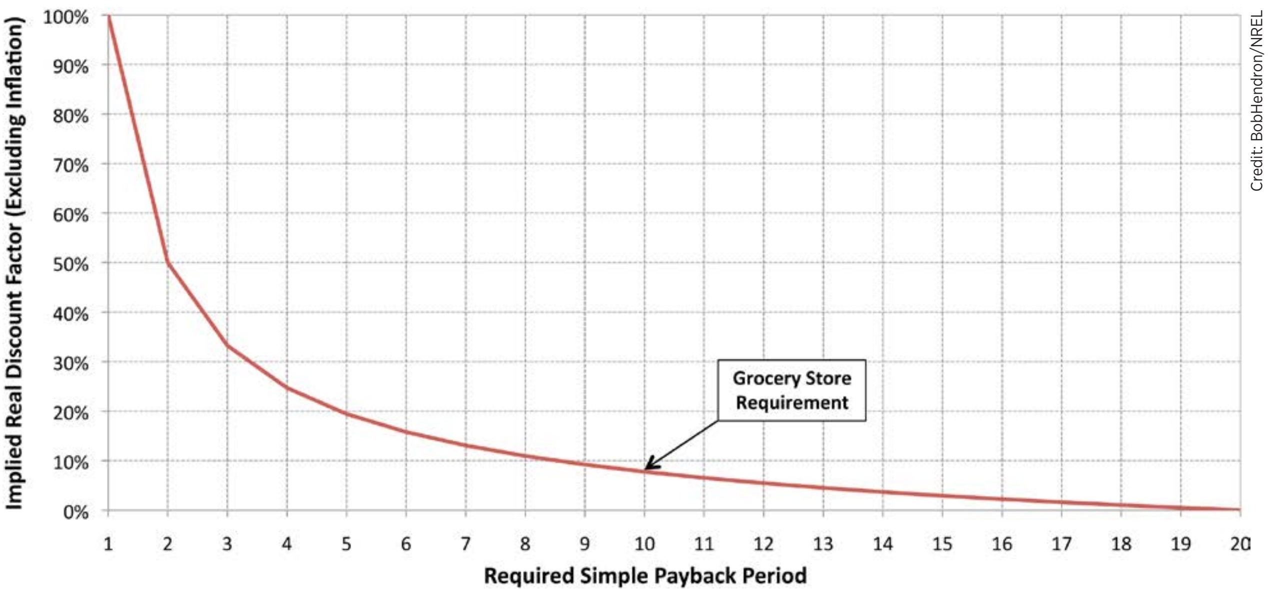

Figure A–1 Implied real discount factor as function of required simple payback period (assumes investment in Year 0 with constant return for 20 years)

Many private sector building owners target a short payback period of 3–5 years for business investments. However, a longer time horizon is usually necessary to achieve significant energy savings for retrofit projects that consist of more than EBCx. We selected 10 years as a reasonable payback period for energy efficiency investments in grocery stores, which is faster than typical ESCO projects in the public sector (Hopper et al. 2005). According to Figure A–1, a required simple payback of 10 years is roughly equivalent to a 7% discount factor.

A.2 Components of Multiyear Cash Flows

There can be a large number of cash flows associated with a particular retrofit measure, both positive and negative. Positive cash flows represent net inflows of money, while negative cash flows represent net outflows or costs. All cash flows are "net" cash flows relative to the reference case. A positive cash flow may be a direct inflow of cash to an organization, such as the sale of equipment or a rebate from the utility company, or it may represent an avoided expenditure, such as energy cost savings or not purchasing replacement equipment when the original equipment would have reached the end of its useful life. Equations A–2 and A–3 identify the cash flows that are the most important for a meaningful NPV calculation. The cash flows are assumed to be in current year dollars (i.e., they do not include the effects of inflation).

$$C_0 = -C_{pur} - C_{inst} + C_{salv,ref} + C_{tax,0} + C_{incent} - (C_{disp} + C_{plan}) \times (1 - R_{tax,inc}) \quad \textbf{(A–2)}$$

Where:

C_{pu} = purchase cost of equipment

C_{inst} = installation cost of measure/package

$C_{salv,ref}$ = salvage value of existing equipment

$C_{tax,0}$ = tax benefits associated with disposing of existing equipment

C_{incent} = NPV of financial incentives (rebates, tax credits, etc.)

C_{disp} = disposal cost of existing equipment

C_{plan} = cost of project planning (= 0 for individual measures)

$R_{tax,inc}$ = federal corporate income tax rate (= 0 for most grocery stores)

$$C_t = [C_{energy,elec} \times (R_{esc,elec})^t + C_{energy,gas,t} \times (R_{esc,gas})^t - C_{om} - C_{mv}] \times (1 - R_{tax,inc}) - C_{repl,eem} + C_{repl,ref} + C_{depr,eem,t} - C_{dpr,ref,t} + C_{rem,eem,20} - C_{rem,ref,20} \quad \textbf{(A–3)}$$

Where:

$C_{energy,elec,t}$ = annual electricity cost savings in Year t

$C_{energy,gas,t}$ = annual natural gas cost savings in Year t

$R_{esc,elect}$ = fuel price escalation rate for electricity = 0.5% (DOE 2011b)

$R_{esc,gas}$ = fuel price escalation rate for natural gas = 2.0% (DOE 2011b)

C_{om} = additional O&M costs (negative if O&M savings)

C_{mv} = additional M&V costs (= 0 for individual measures)

$C_{repl,eem}$ = replacement cost for measure/package (= 0 except at end of useful life)

$C_{repl,ref}$ = replacement cost for reference case (must meet code) (= 0 except at end of useful life)

$C_{depr,eem,t}$ = tax deduction for depreciation of measure/package in Year t

$C_{depr,ref,t}$ = tax deduction for depreciation of existing equipment in Year t

$C_{rem,eem,20}$ = remaining value of measure (= 0 except in year 20)

$C_{rem,ref,20}$ = remaining value of reference equipment (= 0 except in year 20)

Guidance, assumptions, and technical resources for estimating each of these cash flows are presented in the following sections.

A.2.1 Purchase Cost (C_{pur})

The purchase cost of the measure or package of measures includes the cost of equipment and associated materials. It does not include labor costs. If the purchase cost is financed over several years, it should be calculated as the NPV of the loan or lease payments over the term of the project. Purchase cost for a particular product or piece of equipment is relatively consistent from project to project, but may still vary depending on the financing mechanism, volume purchased, presence of local competition, and any negotiated purchasing agreements with suppliers. For staged retrofit projects, there will be multiple purchase costs applied at several points during the 20-year analysis period.

For our example analysis, professional cost-estimating software and databases were used to estimate purchase costs associated with each measure based on the building type (grocery store) and geographic location. We assumed that the investment was funded using the store's capital budget, and no borrowing was necessary. We also assume that the project is a whole-building project with all measures installed in Year 0.

A.2.2 Installation Cost (C_{inst})

Unlike purchase cost, the installation costs associated with a measure can vary dramatically depending on the building being modified and the capabilities of the contractor. Costs may be higher for a variety of reasons:

- Systems are difficult to access.
- Complex integration with existing systems and controls is necessary.
- The work must be done piecemeal or in stages to avoid disrupting building operations.
- Hazardous materials must be removed or controlled (asbestos, mold).

The example analysis for this guide assumes that none of these complications are present, and that typical installation costs based on similar projects in grocery stores can be used, with adjustments for local labor rates. We assume all installation costs occur in Year 0, consistent with a whole-building retrofit.

A.2.3 Salvage Value of Existing Equipment ($C_{salv,ref}$)

For the most part, older equipment and materials removed from a building have very little salvage value. Newer equipment may have more value, but is less likely to be replaced as part of an energy retrofit. In most cases, we assume that equipment cannot be reused, and the value of recyclable components (such as copper, aluminum, and glass) is approximately the same as the cost of hauling the equipment away.

A.2.4 Tax Benefits Associated with Disposing of Existing Equipment ($C_{tax,0}$)

If existing capital equipment is replaced before it is fully depreciated, the difference between the undepreciated value of the equipment (or adjusted basis) and the salvage value (if any) is considered an operating loss, which can be deducted from corporate income taxes. In subsequent years, the depreciation tax deduction that would have been available for the existing equipment is lost. $C_{tax,0}$ is equal to the NPV of these competing tax implications.

A.2.5 Financial Incentives (C_{incent})

Financial incentives from utilities or government entities can take many different forms, including rebates, subsidies, tax credits, accelerated depreciation, low interest loans, guaranteed loans, and free energy audits. As discussed in Section 2.6, DSIRE provides detailed information about nature and size of the incentives available in each state. These incentives can be quite significant, causing marginally cost-effective measures to produce large returns on investment. Financial incentives should not be ignored when evaluating measures for actual retrofit projects. For the example analysis, however, we do not include these incentives because they come and go over time, and our intention is to identify packages of measures that pay for themselves strictly through energy cost savings.

A.2.6 Disposal Cost of Existing Equipment (C_{disp})

Certain materials associated with the existing equipment may require special handling, recycling, or disposal procedures that can increase the overall cost of a measure. Examples include fluorescent lamps, computers, refrigerators, and construction materials containing asbestos. These costs can be very different from one site to another, but generally are not very large compared to other costs associated with a project. For the example analysis, we estimated disposal costs using professional cost estimating methods.

A.2.7 Project Planning (C_{plan})

Overall project planning includes all of the preparatory work conducted by grocery store staff prior to the selection of measures that will be implemented. After that point, management and coordination activities are most easily treated as overhead costs for individual measures. The following costs are examples of those included in project planning category:

- Form the internal project team.
- Perform energy benchmarking activities.
- Conduct a site energy audit.
- Write statements of work for subcontracted activities.
- Review bids and select contractors.

A study by Oak Ridge National Laboratory (Hughes et al. 2003) indicated that these planning costs are approximately $128,000 for a fairly large appropriations-funded retrofit project in a Federal government facility. For the example building analysis, we assume that 50% of this cost is constant, and the other 50% is a linear function of the size of the facility. Depending on the magnitude of the retrofit project and the nature of the processes and procedures that must be followed, a larger or smaller cost estimate for project planning may be appropriate.

A.2.8 Electricity Cost Savings ($C_{energy,elec,t}$) and Natural Gas Cost Savings ($C_{energy,gas,t}$)

Energy savings can be very difficult to calculate without using a sophisticated modeling tool. Even straightforward measures such as lighting improvements have large interactions with space conditioning energy. As a result, we do not recommend using oversimplified techniques to quantify energy savings for complex projects that require large financial commitments and involve significant risk. DOE has assembled summaries of more than 300 building energy simulation tools (*http://apps1.eere.energy.gov/buildings/tools_directory/*), which can be quite helpful for organizations that do not have an established approach for energy analysis and may be seeking expert guidance for selecting the right tool.

Annual electricity cost savings include reductions in electricity use (kilowatt hours) and peak demand (kilowatts), but can also include changes to base utility charges if the store becomes eligible for a different rate schedule. Natural gas cost savings is most often based simply on the volume of gas used (1000 ft^3). Utility rate structures are highly variable depending on geographic location, time of year, and facility size. Therefore, the actual utility rate schedule should be identified and utilized for the purpose of calculating electricity cost savings. If actual utility rates cannot be found, estimated energy prices for each state are published by the U.S. Energy Information Administration (EIA) (*http://www.eia.gov/*).

Energy savings can sometimes change over the life of a project, especially for staged retrofits. For example, if new equipment is not well-maintained, its efficiency may degrade significantly or it may fail prematurely. Our assumption for the example analysis is that comprehensive O&M and M&V protocols are implemented by store management to ensure that the performance of new equipment is sustained. The cash flows associated with O&M and M&V are consistent with this assumption. The energy savings for a retrofit project can also diminish over time because a building must comply with local energy codes when equipment is replaced. If the reference building has a very old gas water heater with 70% thermal efficiency and 5 years of useful life remaining, we can expect that water heater to be replaced in 5 years by a new one with thermal efficiency greater than 80%, as required by the federal equipment standards. As a result, the energy savings for a water heater retrofit measure would diminish in 5 years because the energy use for the reference building would have decreased anyway.

Fuel price escalation rates may be applied to future energy savings cash flows. However, fuel prices are very volatile, and it is very difficult to predict energy prices with any degree of accuracy. The most authoritative reference for fuel price projections is the EIA, which publishes the Annual Energy Outlook (*http://www.eia aeo/*). Fuel price escalation rates should not include the effect of inflation. All values in the cash flow analysis should be in base year dollars.

In our example grocery store analysis, we used the EnergyPlus (*http://apps1.eere.energy.gov/buildings/energyplus*) software to calculate energy savings for each relevant measure and for each package of measures presented in this guide. The actual 2011 electricity price schedules were used for each of the five cities, including appropriate time-of-day and seasonal adjustments, and rate changes associated with peak demand reductions. Natural gas prices were based on either current utility schedules or state average gas prices published by DOE (*http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm*). Fuel price escalation rates were taken from the EIA Annual Energy Outlook 2011 (*http://www.eia aeo/*).

A.2.9 Additional O&M Cost (C_{om})

The effect of retrofit measures on O&M costs can be either positive or negative. Older equipment often breaks down or performs poorly, forcing maintenance personnel to invest a substantial amount of time into keeping it performing at an adequate level. In most cases, new energy efficient equipment is more reliable, reducing the O&M costs associated with the equipment. But some newer equipment may be more complex, and require additional interaction from O&M personnel to keep it running properly.

Many of the EBCx measures discussed in this guide include heightened attention to O&M, such as regularly cleaning coils, replacing filters, calibrating sensors, and adjusting control settings. Ongoing costs associated with commissioning are almost always worthwhile from an energy savings and equipment lifetime perspective, but these costs should be quantified and included in the cash flow analysis in order to create a clear picture of the overall cost-effectiveness of a building improvement project.

A maintenance escalation rate may be applied to O&M costs in future years. In general, this rate is not much higher than the inflation rate, and the effect is small compared to the uncertainty in projecting future O&M costs. We do not recommend using a maintenance escalation rate unless O&M costs are very well defined.

For simplicity, we include what is sometimes referred to as repair and replacement (R&R) costs in the O&M category. Replacements in this category should be limited to components or elements of each measure (such as lamp or filter replacements), not replacement of the entire measure.

For the example building analysis, professional cost estimators provided the relative O&M costs for each measure. In some cases, there was insufficient basis for assuming any change to O&M costs, and a value of zero was used.

A.2.10 Additional M&V Cost (C_{mv})

M&V costs are usually attributed to the project as a whole, but there may be times when the performance of a particular piece of equipment will be tested or tracked very closely. In such cases it may be appropriate to attribute certain M&V costs to the measure itself, to provide a more complete accounting of costs and benefits for that measure.

For the example analysis, we assigned M&V costs to packages of measures as a whole. Consequently, we used a value of zero for C_{mv} when evaluating the NPV of individual measures. For packages of measures, we assumed that annual M&V costs are equal to 5% of the estimated energy cost savings, as discussed in Section 5.

A.2.11 Replacement Cost for Measure ($C_{repl,eem}$)

It should be assumed that each measure is replaced at the end of its useful life with a system of the same type and efficiency. In some cases, replacement cost may be much less than the original installation cost because the infrastructure is already in place and there are records of specific components, vendors, and procedures that were used the first time. In other cases there may be very little difference in cost.

The useful life can be estimated for most common measures using the table of service life estimates in Chapter 37 of the *ASHRAE HVAC Applications Handbook* (ASHRAE 2011). The list is primarily limited to HVAC measures. Estimated useful life estimates for many other measures, including envelope, domestic hot water, lighting, and refrigeration, can be found in life cycle cost analysis guidance published by the State of Washington General Administration (*www.ga.wa.gov/eas/elcca/simulation.html*). Recommended replacement schedules for most building components assemblies can also be found in the *R.S. Means Facilities Maintenance & Repair Cost Data Handbook* (R.S. Means 2009).

Professional cost estimators provided the values of $C_{repl,eem}$ used in our example analysis, which assumes a 20-year analysis period. Most energy efficiency measures that involve mechanical or electrical equipment are replaced at least once during that time period. Envelope measures usually last longer.

A.2.12 Replacement Cost for Reference Case ($C_{repl,ref}$)

In order to correctly evaluate net cash flows associated with a measure, a realistic reference case must be developed for comparison. This reference case must include the equipment replacements and upgrades that would have occurred if the measure was never implemented. In some cases, equipment would be replaced with similar equipment that has the same efficiency. In other cases, the worst-performing new equipment available on the market may be a significant upgrade over the existing equipment. This gradual improvement of the reference case over time also impacts energy savings, as discussed earlier.

Typically, existing equipment is replaced at the end of its useful life. In most scenarios, remaining useful life can be calculated by subtracting equipment age from the useful life estimated using the references discussed in Section A.2.11.

In some cases, equipment may be considered at the end of its useful life because it is broken beyond repair, or there are building modifications underway for nonenergy reasons that necessitate equipment replacement. In such cases, the remaining useful life is zero, and equipment replacement for the reference case happens during the first year of the project analysis period. This allows the consolidation of $C_{repl,ref}$, C_{pur}, and C_{inst} into a single incremental cost for improved equipment over a newer version of the current equipment (or the worst equipment allowed by code). If the replacement equipment lifetimes are the same for both the measure and the reference case, $C_{repl,ref}$ and $C_{repl,eem}$ can also be combined into a single incremental cost for the improved equipment. Otherwise cash flows for equipment replacement must be tracked separately for the two scenarios and assigned to the appropriate year.

For our analysis of retrofit EEMs in the example grocery store, we assumed that all equipment is 50% through its useful life. We used the State of Washington service life estimates to determine the original useful life for existing equipment.

A.2.13 Tax Deductions for Depreciation ($C_{depr,eem,t}$ and $C_{depr,ref,t}$)

The vast majority of EEMs, discussed in this guide are capital expenditures that must be depreciated over a number of years for tax purposes if the store owner is a for-profit entity. The depreciable basis for such measures includes both the purchase cost and the installation cost of the equipment. The use of the Modified Accelerated Cost Recovery System (MACRS) is required by the Internal Revenue Service for most categories of equipment. Certain measures may be treated as operating expenses and deducted immediately, including EBCx measures and equipment with a useful life of less than one year.

If the building owner is a for-profit entity but the project does not include special tax incentives, such as the 179D Federal Energy Tax Deduction, these cash flows largely cancel out and are usually not worth the effort to analyze in detail. In such cases, the NPV can be reduced by the corporate tax rate (usually 35%) to approximate the overall effect of taxes on the investment. For the example analysis, we used a simplified analysis based on straight-line depreciation over the useful life of the equipment.

A.2.14 Remaining Value of Measure and Reference Equipment at the End of the Analysis Period ($C_{rem,eem,20}$ and $C_{rem,ref,20}$)

At the end of the 20-year analysis period, both the measure and the equipment in the reference building are likely to have some remaining value. In order to produce a fair estimate of NPV, an assumption should be made that the equipment is sold at a price equal to the remaining value at Year 20. Unless better information is available for estimating the future value of installed equipment, we recommend that the adjusted basis for depreciation be used as a surrogate. Because the sale price is assumed to equal the “book value” of the equipment, there is no capital loss or gain at the end of the analysis period, and any tax implications can be neglected. The adjusted basis for depreciation is the original purchase and installation cost adjusted according to the MACRS schedule for the corresponding class of equipment (See Table A–1 and Table A–2).

For the example analysis in this guide, we simplified this approach, and assumed a straight line decrease in value over time for both the measure and the reference case. In the context of a grocery store, the effect of the simplification was negligible.

Table A–1 MACRS Depreciation Schedule

Recovery Year	3-Year Property	5-Year Property	7-Year Property	10-Year Property	15-Year Property	20-Year Property
1	33.33	20.00	14.29	10.00	5.00	3.750
2	44.45	32.00	24.49	18.00	9.50	7.219
3	14.81	19.20	17.49	14.40	8.55	6.677
4	7.41	11.52	12.49	11.52	7.70	6.177
5		11.52	8.93	9.22	6.93	5.713
6		5.76	8.92	7.37	6.23	5.285
7			8.93	6.55	5.90	4.888
8			4.46	6.55	5.90	4.522
9				6.56	5.91	4.462
10				6.55	5.90	4.461
11				3.28	5.91	4.462
12					5.90	4.461
13					5.91	4.462
14					5.90	4.461
15					5.91	4.462
16					2.95	4.461
17						4.462
18						4.461
19						4.462
20						4.461
21						2.231

Table A–2 MACRS Property Class Table

Property Class	Personal Property (all property except real estate)
3-year property	• Special handling devices for food and beverage manufacture. • Special tools for the manufacture of finished plastic products, fabricated metal products, and motor vehicles • Property with asset depreciation range (ADR) class life of 4 years or less
5-year property	• Information Systems; Computers / Peripherals • Aircraft and parts (of non-air-transport companies) • Petroleum drilling equipment • Property with ADR class life of more than 4 years and less than 10 years • Certain geothermal, solar, and wind energy properties.
7-year property	• Office furniture, fixtures, and equipment • Property with ADR class life of more than 10 years and less than 16 years • All other property not assigned to another class
10-year property	• Assets used in petroleum refining and certain food products • Vessels and water transportation equipment • Property with ADR class life of 16 years or more and less than 20 years
15-year property	• Telephone distribution plants • Municipal sewage treatment plants • Property with ADR class life of 20 years or more and less than 25 years
20-year property	• Municipal sewers • Property with ADR class life of 25 years or more
Property Class	**Real Property (real estate)**
27.5-year property	• Residential rental property (does not include hotels and motels)
39-year property	• Non-residential real property

Appendix B

Detailed Approach for Selecting Recommended Packages

B.1 Overall Approach

Building energy simulation was intensively used to support the development of this guide. Due to its strong capability to model different HVAC systems and equipment, EnergyPlus version 6.0 was selected as the simulation program to assess and quantify the energy and cost saving potential for individual energy efficiency measures. The NPV was calculated based on the quantified savings for each measure along with the measure implementation cost and other multiyear cash flows (see Appendix A). Measures with a positive NPV were included in the recommended packages. Each package was then further evaluated to determine its total energy saving and cost effectiveness. Further details about the selection of measures for EBCx and whole-building retrofits are provided in Sections B.4 and B.5.

The following steps were followed to conduct the energy simulations in support of this guide:

- **Baseline building model development and evaluation.** A baseline building model was developed as a first step. This model was based on the DOE's Reference model for grocery stores (Deru et al, 2011b). The model was adjusted to reflect the most common building design and operating practices for pre-1980 vintage buildings in each climate location. These modifications are listed in Section B.3.
- **Individual retrofit measure energy savings and cost-effectiveness analysis.** Each retrofit measure was individually evaluated in terms of its energy saving and cost effectiveness. The new model and the reference model used the same hardcoded equipment size and settings such as rooftop unit cooling capacities. Site energy consumption was obtained by running EnergyPlus for the new model. In addition, based on the predefined utility rates, EnergyPlus also calculated the energy cost, including gas and electricity consumption costs and electricity demand cost. The energy cost savings were then used together with the estimated measure implementation cost to calculate cost effectiveness metrics such as simple payback and NPV. Appendix C provides the detailed results for each individual retrofit measure.
- **Retrofit measures categorization.** Based on the energy saving and the cost-effectiveness metrics for the retrofit measures from the previous step, retrofit measures were selected for development of the recommended retrofit packages.
- **Retrofit package energy savings and cost-effectiveness analysis.** After the retrofit package was determined, its overall energy savings and cost effectiveness was estimated as a whole in comparison with the original baseline. The package analysis took into account the interactions between different measures. Hence, the packaged energy saving is not simply the sum of total individual measures. The capacity of equipment that was not directly affected by the measures included in the package stayed the same between the new model and the reference model.

B.2 CRB Characteristics

The reference building for our example analysis is the Pre-1980s Grocery Store Commercial Reference Building (CRB) (Deru et al. 2010), which is one of a series of reference buildings developed by DOE to help standardize the analysis of EEMs when applied to specific building sectors. Although the CRB represents a typical U.S. supermarket, energy and cost savings calculations should not be extrapolated to other individual grocery stores. The

Pre-1980s CRBs represent fairly old buildings, with one or more equipment replacements over 30+ years depending on the typical useful life of each piece of equipment. We did not assume the original equipment is still present in the building.

The CRBs take the form of EnergyPlus models. EnergyPlus is an accurate and flexible modeling program developed by DOE in partnership with modeling experts across the country. The CRB models have been thoroughly vetted by three national laboratories (NREL, Pacific Northwest National Laboratory [PNNL], and LBNL), instilling a high degree of confidence that it is realistic and free of significant errors.

The CRB and recommended packages are tailored to each of five important U.S. climate regions. Simulations performed in support of the AEDGs indicated that there were limited differences in the optimal packages for new commercial buildings in cities within the same climate region. Climate dependence within the same region is expected to be even weaker for retrofit packages, and five locations should be able to provide sufficient diversity of results for this guide. The following climate regions were selected, represented by the city in parenthesis:

- Hot-humid (Miami, Florida)
- Hot-dry (Las Vegas, Nevada)
- Marine (Seattle, Washington)
- Cold (Chicago, Illinois)
- Very Cold (Duluth, Minnesota)

Building owners can use the values in Table B–1 to compare the characteristics of their climate zone with those of the five represented climate zones in this guide. Approximate energy prices for the five cities are presented in Table B–2. Actual 2011 utility rate tariffs, which are considerably more complex, were used to analyze the example building.

Table B–1 Key Climatic Characteristics of the Five Cities Used in the Development of Recommended EEM Packages

Location	Winter Design Temperature (°F)	Summer Design Temperature (°F)	Summer Design Humidity* (% RH)	Annual Heating Degree Days (°F·day)	Annual Cooling Degree Days (°F·day)
Miami	47.7	91.8	53%	130	4,458
Las Vegas	30.5	108.3	11%	2,105	3,348
Seattle	24.5	84.9	34%	4,729	177
Chicago	−4	91.9	45%	6,311	842
Duluth	−19.5	84.5	49%	9,425	209

ASHRAE 2011

*Not coincident with summer design temperature

Table B–2 Approximate Energy Prices for the Five Cities Used in the Analysis of Recommended EEM Packages

Location	Marginal Electricity Rate ($/kWh)	Demand Charge, Summer ($/kW)	Demand Charge, Winter ($/kW)	Duration of Summer Demand Rate (months)	Gas Rate ($/therm)	Energy Tax Rate
Miami	0.054	11.05	11.05	6	1.024	8.0%
Las Vegas	0.067	19.23	0.5	4	0.951	8.0%
Seattle	0.065	5.76	8.65	6	0.984	8.5%
Chicago	0.084	5.75	5.75	4	0.865	8.0%
Duluth	0.083	4.87	4.87	6	0.777	6.0%

A rendering of the CRB model is shown in Figure B–1. Summary information about the building is provided in Table B–3, and the distribution of space types in the building is presented in Table B–4.

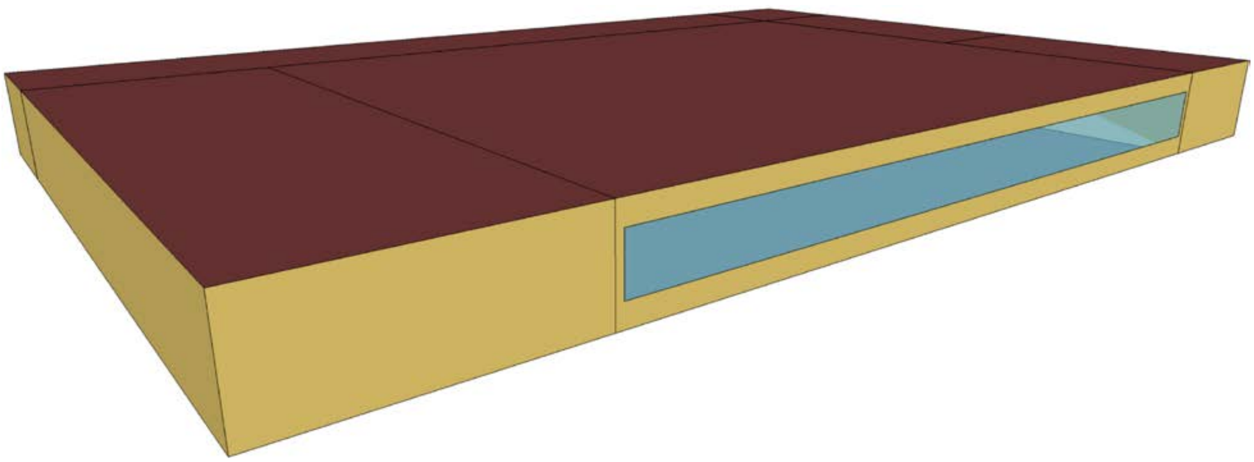

Figure B–1 Rendering of CRB (view from the southwest)

Table B–3 CRB Overview

Square footage	45,000 ft^2
Number of floors	1
Window-to-wall ratio	11%
Wall construction	Mass
Roof construction	Insulation entirely above deck

Table B–4 CRB Space Types and Floor Area Distribution

Space Type	Area (ft²)	% of Total
Bakery	2,250	5.0%
Deli	2,419	5.4%
Dry storage	6,694	14.9%
Office	956	2.1%
Produce	7,657	17.0%
Sales	25,025	55.6%
Total	45,002	100.0%

The CRB is served by six separate HVAC systems, one for each space type. All six systems are packaged single-zone (PSZ) rooftop units. A schematic diagram of the PSZ system type is shown in Figure B–2. Performance characteristics of the PSZ system type are defined in Table B–5.

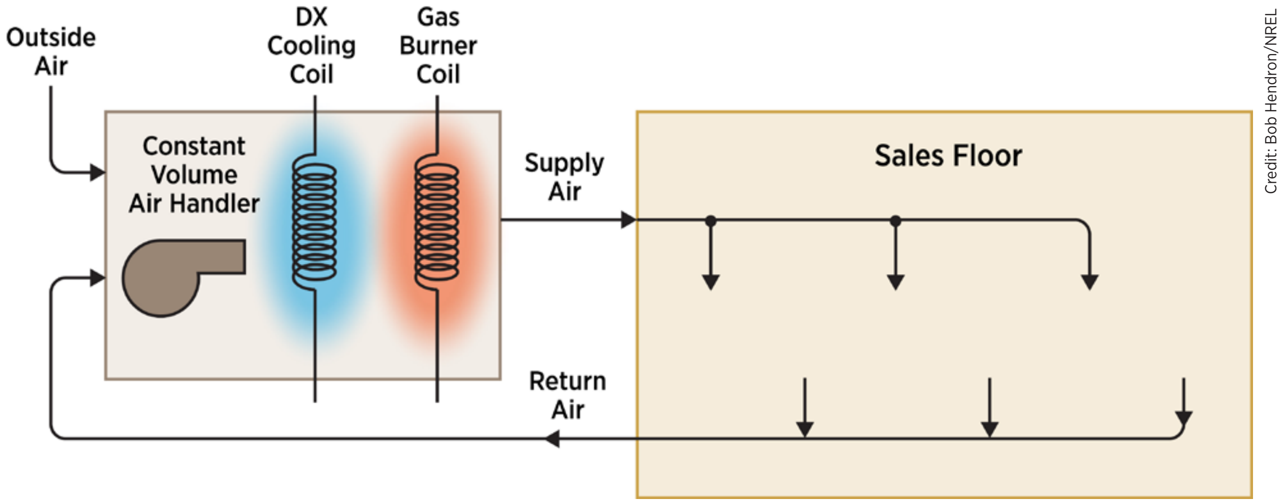

Figure B–2 CRB PSZ system

Table B–5 Performance Specifications for PSZ Systems

Characteristic	Value
Heating system	78% efficient natural gas heating
Cooling system	3.2 coefficient of performance (COP) DX cooling coil
Fan type	Constant speed fan, 60% total fan efficiency
Economizer	Dry bulb air-side economizer, except in Hot & Humid climates

Other details of the CRB can be found in the documentation of the Commercial Reference Buildings (Deru et al. 2011b), in the spreadsheet summary posted online, or in the EnergyPlus input file itself.

B.3 Adjustments to the Supermarket Commercial Reference Building to create the Example Building

The following changes were made to the model of the Pre-1980s Supermarket CRB in order to create an appropriate example building for our purposes. Many of the changes were based on Leach et al. (2009) and NREL's ongoing research to develop a detailed refrigeration benchmark.

B.3.1 Infiltration

- Added extra infiltration to the entry zone in order to model the vestibule measure.
- The infiltration rate was reduced from 50% of the nominal value to 25% during periods when the HVAC system is operating (in accordance with the CRB documentation).
- Changed exhaust fan schedules and infiltration schedules to match store working hours.

B.3.2 Daylighting

- Added visible transmittance to window inputs.
- Changed the ceiling reflectivity from 80% to 70%.

B.3.3 Equipment/Loads

- Changed schedule to turn off deli zone's gas equipment when store is closed.
- Changed the power for the deli exhaust fan from 524 Watts to 925 Watts.
- Split exterior lights object into two objects representing exterior façade lighting and exterior parking lighting.

B.3.4 Refrigeration

- Changed all of the refrigerated case objects designated as "walk-in freezers" or "walk-in coolers" to approximately equivalent walk-in refrigeration objects.
- Set ASH minimum power to be 15% of maximum.
- For refrigerated cases, case credits for open cases were increased to 1.0 during store operating hours; case credits for cases with doors were increased to 0.8 during store operating hours.
- Sales 1, Sales 4 zones: Changed rated latent heat ratio to 0.3 to correspond with multideck open case.
- ASHs were removed from medium temperature (non-frozen) cases and ASH control mode was set to "Constant" for all cases with anti-sweat heaters.
- Powered defrost was removed from medium temperature (non-frozen) cases and walk-ins.
- Defrost control mode was set to "Electric" for all cases with powered defrost and to "Off-Cycle" for all other cases.

B.3.5 HVAC

- Changed HVAC sizing parameters from 1.2 to 1.5 to represent older building design practices.
- Changed from autosizing to hard sizes generated from the baseline model.
- Changed all rooftop units (RTUs) to represent a standard 10-ton unit with COP of 3.47, fan efficiency of 33%, and pressure rise of 404 Pa (381 Pa for Miami, which has no economizer).
- Changed mock exhaust fan flow rates and zone mixing objects so that 15% of the deli exhaust hood flow rate is outdoor make up air with the remaining 85% coming from the sales zone.

B.3.6 Other

- Updated the utility tariffs to 2011 values.

B.4 Selection of Existing Building Commissioning Packages

The DOE CRBs are assumed to be well commissioned. The modeling inputs inherent in the CRBs are not consistent with suboptimal operating schedules, building controls that are no longer active, or degraded equipment performance due to wear and tear. To model the energy savings for EBCx measures, we would have to artificially degrade the performance of the CRB and create a new reference building. Unfortunately, there have been no authoritative studies of typical degradation patterns that would enable us to construct uncommissioned versions of the CRBs with a high degree of confidence. As a result, we did not try to model EBCx measures.

Instead, the recommended EBCx packages were developed based on subjective estimates of the likely energy savings of each measure considered. We estimated energy savings for the EBCx package based on data from actual projects, combined with the CRB physical characteristics and energy use. A seminal study of commissioning projects across the country was conducted by LBNL in 2009 (Mills 2009). This study provides very useful cost and energy savings data as a function of building size for several categories of buildings. Because the energy savings for grocery store projects was a combination of new and existing buildings, we averaged the grocery store savings (12%) and the mean energy savings for all existing buildings (16%) to estimate the expected national average energy savings for existing grocery stores (14%). Adjustments were made for each of the five cities based on modeling of retrofit measures performed by PNNL in support of the Office Building AERG (PNNL and PECI 2011). Peak demand savings (5%), initial cost ($0.31/ft^2), useful life (5 years), and the number of commissioning measures in a typical project (7.3) were estimated based on the LBNL study.

B.5 Selection of Retrofit Packages

The measures included in the recommended retrofit packages were chosen based on the cost effectiveness of each measure when applied to the example building model, using typical equipment costs and actual utility rates. A subset of the retrofit measures discussed in Appendix F was selected for inclusion in the detailed analysis, based on relevance to the example building, likelihood of producing significant energy savings, and complexity of implementation.

Each measure was analyzed individually, and in combination with other measures when system interactions were large. This sequencing allowed for the possibility of downsizing HVAC equipment due to reduced heating and cooling loads. Measures were selected for the recommended packages if their individual NPVs were greater than zero. A more sophisticated analysis might examine measures in various combinations to produce a more optimized package. A final analysis of each recommended package was performed to capture all remaining system interactions and verify that the combined package met the positive NPV requirement. The energy savings for the final recommended retrofit packages do not include the effects of EBCx. If a project includes both EBCx and retrofit measures, there will likely be significant interactions. Therefore, the combined energy savings for the two packages are not strictly additive.

Appendix C

Detailed Analysis of Individual Retrofit Measures in the Example Building

This appendix documents the detailed simulation and cost analysis results that were used as the basis for the recommended retrofit packages for the example building. Table C–1 provides a summary of key results for the 22 individual measures that were analyzed. Most of these measures are discussed in detail in Appendix F, and the others are listed at the end of that appendix under “Additional Measures for Consideration.” The process for selecting measures was described in Section 1.4. All reference case equipment and envelope components were assumed to be halfway through their useful life.

Note: The example building analysis is provided for illustrative purposes only. Costs and energy savings for individual measures can be highly variable and users of this AERG are encouraged to obtain price quotes and perform energy analyses for their specific application.

Table C-1 Summary of Cost-Effectiveness Analysis for Individual Measures

System	EEM Description	Location	% Site Energy Savings (1st Year)	Estimated First Cost	NPV	Simple Payback (Years)	Included in Recommended Package?
Lighting	Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts	Miami	5.6%	$ 136,657	$ 26,119	11.1	Yes
		Las Vegas	4.0%	$ 169,392	$ (2,403)	13.8	No
		Seattle	2.3%	$ 165,611	$ (17,883)	15.6	No
		Chicago	2.5%	$ 182,467	$ (8,477)	14.4	No
		Duluth	1.6%	$ 167,787	$ (7,927)	14.4	No
	Replace incandescent ambient lighting with CFL and accent/display lighting with ceramic metal halide	Miami	2.7%	$ 2,054	$ 58,084	0.4	Yes
		Las Vegas	1.8%	$ 2,650	$ 50,211	0.6	Yes
		Seattle	0.8%	$ 2,560	$ 41,840	0.7	Yes
		Chicago	0.9%	$ 2,881	$ 50,674	0.6	Yes
		Duluth	0.5%	$ 2,574	$ 48,392	0.6	Yes
	Replace refrigerated display case lighting with LEDs	Miami	3.2%	$ 24,385	$ 36,685	4.8	Yes
		Las Vegas	2.9%	$ 36,997	$ 27,597	7.1	Yes
		Seattle	2.4%	$ 34,232	$ 30,292	6.5	Yes
		Chicago	2.3%	$ 41,874	$ 31,541	7.1	Yes
		Duluth	1.9%	$ 34,543	$ 33,350	6.3	Yes
	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient	Miami	0.7%	$ 14,752	$ 3,004	9.4	Yes
		Las Vegas	0.5%	$ 15,423	$ 346	11.2	Yes
		Seattle	0.3%	$ 15,840	$ (3,677)	15.0	No
		Chicago	0.3%	$ 16,626	$ (1,763)	12.8	No
		Duluth	0.2%	$ 15,383	$ (1,679)	12.9	No
	Increase the availability of daylight through the addition of skylights (bundled with photosensors and dimming ballasts)	Miami	8.6%	$ 268,456	$ (112,290)	14.8	No
		Las Vegas	5.3%	$ 284,234	$ (149,396)	17.6	No
		Seattle	2.8%	$ 291,732	$ (195,437)	23.0	No
		Chicago	3.2%	$ 305,507	$ (173,293)	18.9	No
		Duluth	1.7%	$ 306,281	$ (185,170)	19.9	No

Table C-1 Summary of Cost-Effectiveness Analysis for Individual Measures (cont'd)

System	EEM Description	Location	% Site Energy Savings (1st Year)	Estimated First Cost	NPV	Simple Payback (Years)	Included in Recommended Package?
Lighting	Replace metal halide with LED exterior lighting for façades and parking lot, with photocell control	Miami	1.1%	$ 80,827	$ (32,067)	28.0	No
		Las Vegas	1.0%	$ 79,091	$ (28,855)	25.6	No
		Seattle	1.0%	$ 79,397	$ (26,150)	23.5	No
		Chicago	0.9%	$ 73,207	$ (18,216)	19.8	No
		Duluth	0.8%	$ 76,291	$ (22,387)	21.7	No
Plug & process loads	Replace kitchen/deli/ bakery appliances with ENERGY STAR models	Miami	1.1%	$ 58,349	$ (15,187)	24.6	No
		Las Vegas	0.9%	$ 59,471	$ (6,231)	24.6	No
		Seattle	0.6%	$ 62,108	$ (9,317)	28.1	No
		Chicago	0.6%	$ 61,344	$ (15,704)	23.2	No
		Duluth	0.4%	$ 77,965	$ (31,206)	29.2	No
	Install VSD kitchen hood exhaust fans with DCV	Miami	0.1%	$ 14,000	$ 15,250	4.2	Yes
		Las Vegas	0.3%	$ 15,500	$ 15,446	4.4	Yes
		Seattle	0.3%	$ 15,700	$ 16,752	4.3	Yes
		Chicago	0.5%	$ 16,500	$ 18,133	4.3	Yes
		Duluth	0.7%	$ 15,500	$ 19,516	4.0	Yes
Building enclosure	Add reflective roof covering	Miami	0.6%	$ 205,255	$ (82,389)	75.3	No
		Las Vegas	-0.5%	$ 223,259	$ (99,168)	73.3	No
		Seattle	N/A	N/A	N/A	N/A	No
		Chicago	-0.8%	$ 239,851	$ (129,820)	166.4	No
		Duluth	N/A	N/A	N/A	N/A	No
	Install vestibules with inner and outer doors	Miami	0.2%	$ 115,349	$ (87,675)	21.9	No
		Las Vegas	0.5%	$ 124,759	$ (80,791)	18.5	No
		Seattle	1.0%	$ 127,867	$ (84,650)	18.9	No
		Chicago	1.2%	$ 133,579	$ (75,353)	16.6	No
		Duluth	1.5%	$ 149,791	$ (114,019)	22.0	No

Table C-1 Summary of Cost-Effectiveness Analysis for Individual Measures (cont'd)

System	EEM Description	Location	% Site Energy Savings (1st Year)	Estimated First Cost	NPV	Simple Payback (Years)	Included in Recommended Package?
Building enclosure	Add rigid insulating sheathing to roof assembly	Miami	1.1%	$ 326,012	$ (163,923)	45.3	No
		Las Vegas	2.3%	$ 359,418	$ (159,704)	33.4	No
		Seattle	1.9%	$ 366,209	$ (185,959)	43.9	No
		Chicago	2.0%	$ 389,194	$ (193,192)	38.7	No
		Duluth	1.8%	$ 419,250	$ (228,014)	60.8	No
	Add insulation and continuous air barrier to exterior walls	Miami	0.8%	$ 151,464	$ (79,453)	50.1	No
		Las Vegas	2.3%	$ 175,933	$ (78,515)	33.3	No
		Seattle	3.8%	$ 204,768	$ (85,185)	34.1	No
		Chicago	5.3%	$ 266,933	$ (121,233)	29.8	No
		Duluth	6.9%	$ 161,857	$ (36,976)	20.4	No
Refrigeration	Install high efficiency ECM evaporator fan motors	Miami	6.2%	$ 75,500	$ 239,346	2.2	Yes
		Las Vegas	5.6%	$ 89,400	$ 228,807	2.7	Yes
		Seattle	5.0%	$ 88,700	$ 234,944	2.6	Yes
		Chicago	4.5%	$ 99,300	$ 241,879	2.8	Yes
		Duluth	3.9%	$ 89,400	$ 243,834	2.5	Yes
	Install night curtains to reduce load on open refrigerated cases	Miami	5.2%	$ 49,363	$ (49)	6.7	No
		Las Vegas	4.8%	$ 56,688	$ (11,795)	8.1	No
		Seattle	5.5%	$ 56,688	$ 9,494	6.3	No*
		Chicago	5.1%	$ 61,858	$ 16,225	6.2	No*
		Duluth	4.9%	$ 56,749	$ 5,037	6.4	No*
	Install doors on open refrigerated cases	Miami	8.3%	$ 118,989	$ (13,042)	8.2	No
		Las Vegas	9.9%	$ 136,644	$ (31,548)	9.2	No
		Seattle	13.7%	$ 136,644	$ 47,945	6.3	Yes
		Chicago	11.4%	$ 149,107	$ 27,901	6.9	Yes
		Duluth	11.2%	$ 136,793	$ 24,732	6.9	Yes

*This measure is mutually exclusive with doors on open refrigerated cases, which had higher NPVs in Seattle, Chicago, and Duluth

Table C–1 Summary of Cost-Effectiveness Analysis for Individual Measures (cont'd)

System	EEM Description	Location	% Site Energy Savings (1st Year)	Estimated First Cost	NPV	Simple Payback (Years)	Included in Recommended Package?
Refrigeration	Install controls to disable ASHs when dew point is low	Miami	0.3%	$ 8,063	$ (4,624)	12.4	No
		Las Vegas	2.0%	$ 9,164	$ 31,737	2.2	Yes
		Seattle	0.6%	$ 9,180	$ 15,212	3.4	Yes
		Chicago	0.4%	$ 9,876	$ 21,658	2.9	Yes
		Duluth	0.4%	$ 9,183	$ 35,131	2.0	Yes
	Install strip curtains and weather seal walk-in freezer doors	Miami	2.3%	$ 6,100	$ 19,221	2.2	Yes
		Las Vegas	2.4%	$ 7,800	$ 15,875	2.8	Yes
		Seattle	3.4%	$ 8,200	$ 34,888	1.9	Yes
		Chicago	2.7%	$ 9,000	$ 32,175	2.1	Yes
		Duluth	2.6%	$ 7,800	$ 26,197	2.1	Yes
	Install smart defrost controller in walk-in freezers and low-temperature cases	Miami	-0.1%	$ 105,700	$ (69,597)	87.6	No
		Las Vegas	0.9%	$ 114,900	$ (61,927)	42.6	No
		Seattle	0.5%	$ 116,600	$ (65,949)	48.1	No
		Chicago	0.5%	$ 120,800	$ (68,285)	48.0	No
		Duluth	0.5%	$ 115,200	$ (61,820)	42.2	No

Table C-1 Summary of Cost-Effectiveness Analysis for Individual Measures (cont'd)

System	EEM Description	Location	% Site Energy Savings (1st Year)	Estimated First Cost	NPV	Simple Payback (Years)	Included in Recommended Package?
HVAC: heating and cooling	Replace inefficient motors with rightsized NEMA premium efficiency	Miami	0.0%	$ 23,300	$ 86,317	1.8	Yes
		Las Vegas	0.0%	$ 24,700	$ 85,485	2.0	Yes
		Seattle	0.0%	$ 25,200	$ 85,208	2.0	Yes
		Chicago	0.0%	$ 25,500	$ 85,018	2.0	Yes
		Duluth	0.0%	$ 24,800	$ 85,435	2.0	Yes
	Convert constant volume or dual duct air handling systems to variable air volume	Miami	3.1%	$ 18,900	$ 36,977	3.2	Yes
		Las Vegas	2.3%	$ 20,800	$ 43,482	3.0	Yes
		Seattle	0.1%	$ 21,000	$ 22,890	4.1	Yes
		Chicago	1.0%	$ 21,900	$ 65,077	2.4	Yes
		Duluth	0.1%	$ 20,700	$ 80,023	2.0	Yes
HVAC: ventilation	Upgrade to DCV to reduce outdoor airflow during partial occupancy	Miami	1.7%	$ 24,820	$ 1,757	9.1	Yes
		Las Vegas	4.2%	$ 32,300	$ 16,662	7.0	Yes
		Seattle	7.3%	$ 27,700	$ 41,569	4.6	Yes
		Chicago	8.1%	$ 28,900	$ 56,006	3.9	Yes
		Duluth	10.0%	$ 28,000	$ 57,086	3.9	Yes
	Add energy recovery to ventilation system	Miami	1.1%	$ 642,300	$ (704,134)	43.3	No
		Las Vegas	3.3%	$ 681,600	$ (724,782)	38.7	No
		Seattle	5.8%	$ 696,300	$ (726,512)	36.8	No
		Chicago	6.3%	$ 704,300	$ (726,433)	35.5	No
		Duluth	8.0%	$ 683,400	$ (708,925)	36.4	No

C.1 Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts

C.1.1. Implementation in Example Building

Ninety-three percent of the ambient lighting in the example building was provided by T-12 fluorescent lamps, mounted in two-lamp fixtures with magnetic ballasts. In total, 2382 T-12 lamps were replaced with T-8 lamps and 1191 magnetic ballasts were replaced with instant-start electronic ballasts. The measure was modeled by reducing the lighting power density in each affected zone. There is a net reduction in relamping costs because T-8 lamps tend to operate at a lower temperature and have a longer average life, and most high performance T-8 lamps come with a maintenance warranty.

C.1.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–2.

Table C–2 Key Results of Energy Savings Analysis for T-8 Lamps and Ballasts

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings* (1st Year)
Miami	5.6%	157,598	-309	$13,384	$2,049
Las Vegas	4.0%	153,198	-1316	$12,101	$2,690
Seattle	2.3%	141,355	-2384	$10,006	$2,586
Chicago	2.5%	145,027	-2019	$12,346	$2,912
Duluth	1.6%	141,330	-2676	$11,522	$2,458

*O&M includes relamping for lighting measures

C.1.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–3.

Table C–3 Key Results of Cost-Effectiveness Analysis for T-8 Lamps and Ballasts

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$71,127	$65,530	$26,119	11.1	Yes
Las Vegas	$70,151	$99,241	($2,403)	13.8	No
Seattle	$73,619	$91,992	($17,883)	15.6	No
Chicago	$69,940	$112,527	($8,477)	14.4	No
Duluth	$74,960	$92,827	($7,927)	14.4	No

C.2 Replace incandescent ambient lighting with CFL and accent/display lighting with ceramic metal halide

C.2.1 Implementation in Example Building

The example building had a significant amount of incandescent lighting. For this measure: 110 incandescent lamps providing ambient lighting (primarily in offices and storage areas) were replaced with CFLs; 190 tungsten halogen lamps providing accent and display lighting were replaced with ceramic metal halide (CMH) lamps; 26 exit signs with incandescent lighting were replaced with LED models; and 5 T-8 office task lights were replaced with LED models. In all cases, replacement lamps produced equivalent light output. O&M costs were reduced on the basis of increased lamp life for the implemented lamps (sevenfold for CFL lamps; fourfold or more for LED lamps; and threefold for CMH lamps).

C.2.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–4.

Table C–4 Key Results of Energy Savings Analysis for CFL and Accent/Display Lighting Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings* (1st Year)
Miami	2.7%	79,650	–226	$6,468	$1,327
Las Vegas	1.8%	77,278	–912	$5,622	$1,304
Seattle	0.8%	70,526	–1600	$4,563	$1,367
Chicago	0.9%	72,465	–1355	$5,783	$1,288
Duluth	0.5%	70,526	–1724	$5,423	$1,312

*O&M includes relamping for lighting measures

C.2.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–5.

Table C–5 Key Results of Cost-Effectiveness Analysis for CFL and Accent/Display Lighting Retrofit

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$858	$1,196	$58,084	0.4	Yes
Las Vegas	$836	$1,814	$50,211	0.6	Yes
Seattle	$882	$1,678	$41,840	0.7	Yes
Chicago	$828	$2,053	$50,674	0.6	Yes
Duluth	$880	$1,694	$48,392	0.6	Yes

C.3 Replace refrigerated display case lighting with LEDs

C.3.1 Implementation in Example Building

Refrigerated display case lighting in the example building was provided by T-12 fluorescent lamps. For this measure, 303 T-12 lamps were replaced with LED lamp strips producing equivalent light output. Because LEDs have approximately 2.5 times the life of T-12 fluorescent lamps, a net reduction in O&M costs was also applied.

C.3.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–6.

Table C–6 Key Results of Energy Savings Analysis for LED Refrigerated Case Lighting Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings* (1st Year)
Miami	3.2%	84,500	0	$6,642	$155
Las Vegas	2.9%	82,497	0	$6,551	$102
Seattle	2.4%	78,017	0	$6,646	$127
Chicago	2.3%	79,150	0	$7,502	$62
Duluth	1.9%	77,581	0	$7,082	$117

*O&M includes relamping for lighting measures

C.3.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–7.

Table C–7 Key Results of Cost-Effectiveness Analysis for LED Refrigerated Case Lighting Retrofit

Location	Purchase Cost	Installation First Cost*	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$0	$24,385	$36,685	4.8	Yes
Las Vegas	$0	$36,997	$27,597	7.1	Yes
Seattle	$0	$34,232	$30,292	6.5	Yes
Chicago	$0	$41,874	$31,541	7.1	Yes
Duluth	$0	$34,543	$33,350	6.3	Yes

*Includes both purchase and installation.

C.4 Install photosensors and dimming ballasts to dim lights when daylighting is sufficient

C.4.1 Implementation in Example Building

This measure was applied to the area of the sales zone within 20 ft of the glazing on the front façade of the building. The model calculated the necessary electric lighting to achieve 46.5 foot-candles of illumination at a point 15 ft from the windows and 3 ft from the floor. To facilitate lighting power reduction in the presence of daylight, one photosensor and 78 dimmable ballasts were installed.

C.4.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–8.

Table C–8 Key Results of Energy Savings Analysis for Photosensors

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings* (1st Year)
Miami	0.7%	20,354	-32	$1,884	$0
Las Vegas	0.5%	18,781	-157	$1,627	$0
Seattle	0.3%	17,089	-307	$1,170	$0
Chicago	0.3%	17,354	-247	$1,489	$0
Duluth	0.2%	16,949	-321	$1,373	$0

* O&M includes relamping for lighting measures

C.4.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–9.

Table C–9 Key Results of Cost-Effectiveness Analysis for Photosensors

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$12,145	$2,607	$3,004	9.4	Yes
Las Vegas	$11,467	$3,956	$346	11.2	Yes
Seattle	$12,180	$3,660	($3,677)	15.0	No
Chicago	$12,149	$4,477	($1,763)	12.8	No
Duluth	$11,689	$3,693	($1,679)	12.9	No

C.5 Increase the availability of daylight through the addition of skylights (bundled with photosensors and dimming ballasts)

C.5.1 Implementation in Example Building

Based on the assumption that skylights can be used to facilitate daylighting in all grocery space types, this measure was applied to the entire store. Eighty-four 4-ft × 4-ft skylights were installed throughout the building, amounting to a total roof coverage area fraction of 3%. The model calculated the necessary electric lighting to achieve 46.5 foot-candles 3 ft from the floor at the center of each daylit zone, based on Leach et al (2009). To facilitate lighting power reduction in the presence of daylight, 7 photosensors and 1,191 dimmable ballasts were installed.

C.5.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–10.

Table C–10 Key Results of Energy Savings Analysis for Skylights

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	8.6%	240,202	–335	$17,773	($732)
Las Vegas	5.3%	201,574	–1691	$15,291	($1,057)
Seattle	2.8%	175,801	–2999	$10,371	($999)
Chicago	3.2%	191,698	–2729	$15,040	($1,303)
Duluth	1.7%	180,624	–3834	$13,183	($790)

C.5.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–11.

Table C–11 Key Results of Cost-Effectiveness Analysis for Skylights

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$219,304	$49,153	($112,290)	14.8	No
Las Vegas	$211,092	$73,142	($149,396)	17.6	No
Seattle	$223,489	$68,243	($195,437)	23.0	No
Chicago	$219,850	$85,656	($173,293)	18.9	No
Duluth	$243,348	$62,933	($185,170)	19.9	No

C.6 Install more efficient exterior lighting for façades and parking lot

C.6.1 Implementation in Example Building

Metal halide lamps were assumed for all façade and parking lot lighting in the example building. When implementing this measure, we replaced all metal halide lighting on the façade and in the parking lot with LED lighting. We assumed motion sensors could be used to control the level of lighting in the parking lot based on whether or not anyone was present. In addition, we assumed that photosensors would be used to automatically turn lamps off during the day. A net reduction in O&M costs resulted from the combination of longer LED life with higher relamping costs.

C.6.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–12.

Table C–12 Key Results of Energy Savings Analysis for Exterior Lighting Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Saving (1st Year)
Miami	1.1%	29,888	0	$1,766	$892
Las Vegas	1.0%	29,837	0	$1,796	$1,146
Seattle	1.0%	29,789	0	$2,216	$1,101
Chicago	0.9%	29,841	0	$2,537	$1,299
Duluth	0.8%	29,803	0	$2,450	$1,093

*O&M includes relamping for lighting measures

C.6.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–13.

Table C–13 Key Results of Cost-Effectiveness Analysis for Exterior Lighting Retrofit

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$77,254	$3,573	($32,067)	28.0	No
Las Vegas	$72,942	$6,149	($28,855)	25.6	No
Seattle	$77,478	$1,919	($26,150)	23.5	No
Chicago	$70,860	$2,347	($18,216)	19.8	No
Duluth	$74,355	$1,936	($22,387)	21.7	No

C.7 Replace kitchen/deli/bakery appliances with ENERGY STAR models

C.7.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–14.

Table C–14 Key Results Of Energy Savings Analysis for Kitchen Appliance Replacement

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	1.1%	29,770	–6	$2,405	$394
Las Vegas	0.9%	27,710	–56	$2,242	$569
Seattle	0.6%	24,486	–148	$2,022	$538
Chicago	0.6%	25,846	–166	$2,358	$701
Duluth	0.4%	24,531	–364	$2,055	$425

C.7.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–15.

Table C–15 Key Results of Cost-Effectiveness Analysis For Kitchen Appliance Replacement

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$54,944	$3,405	($5,187)	24.6	No
Las Vegas	$54,550	$4,921	($6,231)	24.6	No
Seattle	$57,458	$4,651	($9,317)	28.1	No
Chicago	$55,281	$6,062	($5,704)	23.2	No
Duluth	$74,289	$3,676	($31,206)	29.2	No

C.8 Install variable speed drives on kitchen exhaust hood fans with demand control ventilation

C.8.1 Implementation in Example Building

We assumed that the example building has one Type 1 and two Type 2 kitchen exhaust hoods, removing 1,250 cfm and 2,500 cfm (1,250 cfm each) of exhaust air respectively. To represent the EEM, a 30% reduction in average exhaust flow rate due to demand control was applied based on a study of five projects conducted by the Food Service Technology Center (Fisher 2008). An efficiency of 69% was assumed for the VSD (DOE 2008b), resulting in a net reduction in average power of 50%. Flow rate control based on both temperature and optical sensors was assumed. The effect of reduced exhaust flow on total infiltration was not modeled.

C.8.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–16.

Table C–16 Key Results of Energy Savings Analysis for Kitchen Exhaust Hood Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.1%	1,596	0	$146	$3,400
Las Vegas	0.3%	2,290	172	$346	$3,400
Seattle	0.3%	2,593	282	$525	$3,400
Chicago	0.5%	2,366	520	$740	$3,400
Duluth	0.7%	2,474	797	$814	$3,400

C.8.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–17.

Table C–17 Key Results of Cost-Effectiveness Analysis for Kitchen Exhaust Hood Retrofit

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$10,900	$3,100	$15,250	4.2	Yes
Las Vegas	$11,100	$4,400	$15,446	4.4	Yes
Seattle	$11,500	$4,200	$16,752	4.3	Yes
Chicago	$11,000	$5,500	$18,133	4.3	Yes
Duluth	$11,100	$4,400	$19,516	4.0	Yes

C.9 Add reflective roof covering

C.9.1 Implementation in Example Building

The roof of the example building was assumed to have a gray rubber exterior finish that reflects 30% of incident sunlight. The EEM was assumed to be a high albedo white PVC material that reflects 86% of incident sunlight. No change to the thermal insulation levels was assumed. A small reduction in O&M costs was assumed because of lower roof temperatures. This measure was only evaluated in hot climates.

C.9.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–18.

Table C–18 Key Results of Energy Savings Analysis for Reflective Roof

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.6%	22,449	–186	$2,482	$563
Las Vegas	–0.5%	23,790	1335	$2,106	$813
Seattle	N/A	N/A	N/A	N/A	N/A
Chicago	–0.8%	3,459	–1027	($486)	$1,002
Duluth	N/A	N/A	N/A	N/A	N/A

C.9.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–19.

Table C–19 Key Results of Cost-Effectiveness Analysis for Reflective Roof

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$162,190	$43,066	($82,389)	75.3	No
Las Vegas	$161,027	$62,232	($99,168)	73.3	No
Seattle	N/A	N/A	N/A	N/A	No
Chicago	$163,186	$76,665	($129,820)	166.4	No
Duluth	N/A	N/A	N/A	N/A	No

C.10 Install vestibules with inner and outer doors

C.10.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–20.

Table C–20 Key Results of Energy Savings Analysis for Vestibule

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.2%	5,856	28	$696	$3,377
Las Vegas	0.5%	4,114	398	$1,079	$4,880
Seattle	1.0%	959	1060	$1,235	$4,612
Chicago	1.2%	1,662	1335	$1,550	$6,012
Duluth	1.5%	739	1984	$1,556	$3,646

C.10.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–21.

Table C–21 Key Results of Cost-Effectiveness Analysis for Vestibule

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$92,712	$22,637	($87,675)	21.9	No
Las Vegas	$92,048	$32,711	($80,791)	18.5	No
Seattle	$96,954	$30,913	($84,650)	18.9	No
Chicago	$93,282	$40,297	($75,353)	16.6	No
Duluth	$125,356	$24,435	($114,019)	22.0	No

C.11 Add rigid insulating sheathing to roof assembly

C.11.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–22.

Table C–22 Key Results of Energy Savings Analysis for Roof Insulation Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	1.1%	21,594	254	$3,157	$3,940
Las Vegas	2.3%	31,691	1199	$5,540	$5,694
Seattle	1.9%	8,831	1730	$2,734	$5,381
Chicago	2.0%	7,463	2106	$2,921	$7,014
Duluth	1.8%	3,038	2273	$1,980	$4,253

C.11.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–23.

Table C–23 Key Results of Cost-Effectiveness Analysis for Roof Insulation Retrofit

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$246,974	$79,038	($163,923)	45.3	No
Las Vegas	$245,204	$114,214	($159,704)	33.4	No
Seattle	$258,274	$107,936	($185,959)	43.9	No
Chicago	$248,491	$140,703	($193,192)	38.7	No
Duluth	$333,933	$85,317	($228,014)	60.8	No

C.12 Add insulation and continuous air barrier to exterior walls

C.12.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–24.

Table C–24 Key Results of Energy Savings Analysis for Wall Insulation Retrofit

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.8%	24,761	-87	$1,879	$1,013
Las Vegas	2.3%	24,083	1482	$4,017	$1,464
Seattle	3.8%	16,137	3494	$4,939	$1,384
Chicago	5.3%	17,514	5733	$7,234	$1,804
Duluth	6.9%	16,633	8792	$7,886	$1,094

C.12.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–25.

Table C–25 Key Results of Cost-Effectiveness Analysis for Wall Insulation Retrofit

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$94,954	$56,510	($79,453)	50.1	No
Las Vegas	$94,274	$81,659	($78,515)	33.3	No
Seattle	$127,598	$77,170	($85,185)	34.1	No
Chicago	$166,335	$100,598	($121,233)	29.8	No
Duluth	$100,858	$60,998	($36,976)	20.4	No

C.13 Install high efficiency ECM evaporator fan motors

C.13.1 Implementation in Example Building

This measure replaced standard shaded pole evaporator fans and permanent split capacitor (PSC) evaporator fans with electronically commuted motor (ECM) evaporator fans in refrigerated cases and walk-ins, respectively. In total, 207 evaporator fans were replaced: 148 standard shaded pole fans and 59 PSC fans.

C.13.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–26.

Table C–26 Key Results of Energy Savings Analysis for High Efficiency Evaporator Fans

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	6.2%	165,210	0	$11,809	$24,240
Las Vegas	5.6%	162,104	0	$11,661	$24,240
Seattle	5.0%	155,221	0	$12,364	$24,240
Chicago	4.5%	156,903	0	$14,228	$24,240
Duluth	3.9%	154,759	0	$13,607	$24,240

C.13.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–27.

Table C–27 Key Results of Cost-Effectiveness Analysis for High Efficiency Evaporator Fans

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$45,200	$30,300	$239,346	2.2	Yes
Las Vegas	$45,700	$43,700	$228,807	2.7	Yes
Seattle	$47,400	$41,300	$234,944	2.6	Yes
Chicago	$45,500	$53,800	$241,879	2.8	Yes
Duluth	$45,900	$43,500	$243,834	2.5	Yes

C.14 Install night curtains to reduce load on open refrigerated cases

C.14.1 Implementation in Example Building

This measure was applied to all refrigerated display cases without doors. One hundred twenty-seven curtains were installed to cover 103 open cases. Installation of night curtains reduced case infiltration during off hours (10 pm–6 am).

C.14.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–28.

Table C–28 Key Results of Energy Savings Analysis for Night Curtains

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	5.2%	124,988	444	$7,653	$844
Las Vegas	4.8%	82,964	1848	$6,503	$1,220
Seattle	5.5%	90,723	2737	$9,307	$1,153
Chicago	5.1%	87,433	3086	$10,317	$1,503
Duluth	4.9%	80,790	3861	$9,408	$911

C.14.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–29.

Table C–29 Key Results of Cost-Effectiveness Analysis for Night Curtains

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$33,483	$15,880	($ 49)	6.7	No
Las Vegas	$33,791	$22,897	($11,795)	8.1	No
Seattle	$35,022	$21,666	$9,494	6.3	No*
Chicago	$33,668	$28,190	$16,225	6.2	No*
Duluth	$33,976	$22,774	$5,037	6.4	No*

*This measure is mutually exclusive with doors on open refrigerated cases (Section C.15), which had higher NPVs in Seattle, Chicago, and Duluth

C.15 Install doors on open refrigerated cases

C.15.1 Implementation in Example Building

This measure was applied to 271 ft. of open, medium temperature, multideck meat and dairy cases. External loads were reduced by about 80%. The doors included LED lighting, reducing lighting energy by 86% in these cases. The doors did not include anti-sweat heaters. The cost of this measure was assumed to be $500 per foot of case length, based on vendor quotes and actual installation costs in several projects. Costs for refrigerated case doors can be highly variable and users of this AERG are encouraged to obtain price quotes appropriate for their application.

C.15.2 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–30.

Table C–30 Key Results of Energy Savings Analysis for Installing Doors on Refrigerated Cases

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	8.3%	186,761	1,185	$14,290	$713
Las Vegas	9.9%	127,889	5,293	$13,597	$996
Seattle	13.7%	157,239	9,535	$23,222	$949
Chicago	11.4%	152,131	8,376	$22,412	$1,208
Duluth	11.2%	144,783	10,442	$20,770	$755

C.15.3 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–31.

Table C–31 Key Results of Cost-Effectiveness Analysis for Installing Doors on Refrigerated Cases

Location	Purchase Cost*	Installation First Cost*	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$118,989	$0	($13,042)	8.2	No
Las Vegas	$136,644	$0	($31,548)	9.2	No
Seattle	$136,644	$0	$47,945	6.3	Yes
Chicago	$149,107	$0	$27,901	6.9	Yes
Duluth	$136,793	$0	$24,732	6.9	Yes

*Purchase cost includes both purchase and installation costs

The results of the energy simulations are summarized in Table C–30.

C.16 Install controls to disable anti-sweat heaters when dew point is low

C.16.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–32.

Table C–32 Key Results of Energy Savings Analysis for Anti-Sweat Heater Controls

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.3%	12,633	–132	$610	$ –
Las Vegas	2.0%	107,677	–1687	$5,649	$ –
Seattle	0.6%	69,284	–1739	$3,536	$ –
Chicago	0.4%	76,208	–2078	$4,486	$ –
Duluth	0.4%	96,244	–2765	$6,191	$ –

C.16.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–33.

Table C–33 Key Results of Cost-Effectiveness Analysis for Anti-Sweat Heater Controls

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$5,780	$2,283	($4,624)	12.4	No
Las Vegas	$5,845	$3,319	$31,737	2.2	Yes
Seattle	$6,071	$3,109	$15,212	3.4	Yes
Chicago	$5,812	$4,064	$21,658	2,9	Yes
Duluth	$5,864	$3,319	$35,131	2.0	Yes

C.17 Install strip curtains and weather seal walk-in freezer doors

C.17.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–34.

Table C–34 Key Results of Energy Savings Analysis for Strip Curtains and Weather Seals

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	2.3%	48,070	416	$3,498	$338
Las Vegas	2.4%	30,615	1279	$3,141	$488
Seattle	3.4%	36,672	2340	$5,582	$461
Chicago	2.7%	37,159	1968	$5,265	$601
Duluth	2.6%	33,227	2327	$4,613	$365

C.17.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–35

Table C–35 Key Results of Cost-Effectiveness Analysis for Strip Curtains and Weather Seals

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$2,300	$3,800	$19,221	2.2	Yes
Las Vegas	$2,300	$5,500	$15,875	2.8	Yes
Seattle	$2,400	$5,800	$34,888	1.9	Yes
Chicago	$2,300	$6,700	$32,175	2.1	Yes
Duluth	$2,400	$5,400	$26,197	2.1	Yes

C.18 Install smart defrost controller in walk-in freezers and low-temperature cases

C.18.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–36. Note that in Miami, the smart defrost controller performed slightly worse than the standard defrost controller in the example building. With a more optimized control strategy, this measure would likely perform better.

Table C–36 Key Results of Energy Savings Analysis for Smart Defrost Controllers

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	–0.1%	–1,348	0	($92)	$ –
Las Vegas	0.9%	24,999	0	$1,676	$ –
Seattle	0.5%	16,638	0	$1,299	$ –
Chicago	0.5%	16,436	0	$1,351	$ –
Duluth	0.5%	20,957	0	$1,715	$ –

C.18.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–37.

Table C–37 Key Results of Cost-Effectiveness Analysis for Smart Defrost Controllers

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$86,900	$18,800	($69,597)	87.6	No
Las Vegas	$87,800	$27,100	($61,927)	42.6	No
Seattle	$91,000	$25,600	($65,949)	48.1	No
Chicago	$87,400	$33,400	($68,285)	48.0	No
Duluth	$88,200	$27,000	($61,820)	42.2	No

C.19 Replace inefficient motors with right-sized NEMA premium efficiency

C.19.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–38.

Table C–38 Key Results of Energy Savings Analysis for Premium Efficiency Motors

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	0.0%	25	0	$2	$12,900
Las Vegas	0.0%	25	0	$2	$12,900
Seattle	0.0%	25	0	$2	$12,900
Chicago	0.0%	28	0	$3	$12,900
Duluth	0.0%	29	0	$3	$12,900

C.19.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–39.

Table C–39 Key Results of Cost-Effectiveness Analysis for Premium Efficiency Motors

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$20,600	$2,700	$86,317	1.8	Yes
Las Vegas	$20,800	$3,900	$85,485	2.0	Yes
Seattle	$21,500	$3,700	$85,208	2.0	Yes
Chicago	$20,700	$4,800	$85,018	2.0	Yes
Duluth	$20,900	$3,900	$85,435	2.0	Yes

C.20 Convert constant volume or dual duct air handling systems to variable air volume

C.20.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–40.

Table C–40 Key Results of Energy Savings Analysis for VAV Systems

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	3.1%	98,145	–471	$7,512	$ –
Las Vegas	2.3%	139,788	–2515	$8,885	$ –
Seattle	0.1%	126,394	–4164	$6,480	$ –
Chicago	1.0%	177,892	–4904	$12,163	$ –
Duluth	0.1%	208,098	–6995	$13,971	$ –

C.20.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–41.

Table C–41 Key Results of Cost-Effectiveness Analysis for VAV Systems

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$15,100	$3,800	$36,977	3.2	Yes
Las Vegas	$15,300	$5,500	$43,482	3.0	Yes
Seattle	$15,800	$5,200	$22,890	4.1	Yes
Chicago	$15,200	$6,700	$65,077	2.4	Yes
Duluth	$15,300	$5,400	$80,023	2.0	Yes

C.21 Upgrade to demand control ventilation to reduce outdoor airflow during partial occupancy

C.21.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–42.

Table C–42 Key Results of Energy Savings Analysis for Demand-Controlled Ventilation

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	1.7%	41,212	169	$4,179	($1,000)
Las Vegas	4.2%	27,563	3157	$6,914	($1,301)
Seattle	7.3%	7,858	7511	$8,798	($1,116)
Chicago	8.1%	13,185	9188	$10,631	($1,164)
Duluth	10.0%	6,213	13364	$10,516	($1,128)

C.21.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–43.

Table C–43 Key Results of Cost-Effectiveness Analysis for Demand-Controlled Ventilation

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$19,820	$5,000	$1,757	9.1	Yes
Las Vegas	$20,100	$12,200	$16,662	7.0	Yes
Seattle	$20,800	$6,900	$41,569	4.6	Yes
Chicago	$20,000	$8,900	$56,006	3.9	Yes
Duluth	$20,800	$7,200	$57,086	3.9	Yes

C.22 Add heat/energy recovery to ventilation system (requires RTU replacement)

C.22.1 Energy Savings Analysis

The results of the energy simulations are summarized in Table C–44.

Table C–44 Key Results of Energy Savings Analysis for Energy Recovery Ventilation

Location	% Site Energy Savings (1st Year)	Electricity Savings (kWh) (1st Year)	Natural Gas Savings (therms) (1st Year)	Energy Cost Savings (1st Year)	O&M Cost Savings (1st Year)
Miami	1.1%	21,528	235	$2,577	($6,423)
Las Vegas	3.3%	17,498	2612	$5,329	($6,816)
Seattle	5.8%	507	6206	$6,754	($6,963)
Chicago	6.3%	1,761	7484	$7,758	($7,043)
Duluth	8.0%	-2,300	10842	$6,889	($6,834)

C.22.2 Cash Flow Analysis

The results of the cost-effectiveness analysis are summarized in Table C–45. It was assumed in the analysis that RTU replacement was necessary due to space constraints on the roof of the store.

Table C–45 Key Results of Cost-Effectiveness Analysis for Energy Recovery Ventilation

Location	Purchase Cost	Installation First Cost	NPV	Simple Payback (Years)	Include in Recommended Package?
Miami	$567,900	$74,400	($704,134)	43.3	No
Las Vegas	$574,200	$107,400	($724,782)	38.7	No
Seattle	$594,800	$101,500	($726,512)	36.8	No
Chicago	$572,000	$132,300	($726,433)	35.5	No
Duluth	$576,500	$106,900	($708,925)	36.4	No

Appendix D

Prioritization of All Measures Considered

A total of 183 measures were originally considered for this guide, based on the existing literature and several grocery store case studies. As discussed in Section 1.4, this list was narrowed down in several stages to determine the most important measures to describe in the guide, and the measures that were most appropriate to evaluate in the example building analysis. Table D–1 and Table D–2 provide the full list of EBCx and retrofit measures that were considered, along with the recommended prioritization when considering a retrofit project.

Table D–1 Prioritization of EBCx Measures

Priority	EEM Description
1. Recommended in example packages	Raise set points in refrigerated cases when possible
	Clean and calibrate humidity sensors that control ASHs
	Verify correct charge in refrigeration systems, and repair any refrigerant leaks
	Verify optimal head and suction pressures
	Verify correct operation of OA economizer (except Cold and Very Cold)
	Increase thermostat set-back/set-up when building is unoccupied (except Cold and Very Cold)
	Test, adjust, and balance (TAB) air handlers and flow modulation devices to ensure that conditioned air volumes meet load requirements
	Suspend ventilation during unoccupied periods
2. Important measures that should be considered for all projects (discussed in this guide)	Obtain lower electricity rates (where available) by allowing the utility to disable non-essential equipment during peak load periods or by participating in a demand response program
	Schedule cooking activities to use equipment at full capacity
	Verify that airflow paths around transformers are not blocked
	Verify balanced 3-phase power and proper voltage levels
	Control computer power-management settings facility-wide through software or logon scripts, ensuring settings can't be overridden
	Ensure that open refrigerated cases are covered when store is closed
	Calibrate any existing lighting controls and optimize settings based on building usage patterns and daylight availability
	For fixtures with one or more burned out lamps, replace all lamps with lower wattage versions that produce equivalent or superior light output and quality
	Repair/replace gaskets and seals on refrigerated cases
	Adjust light levels to within 10% of the IES recommendations for the tasks conducted in each area by delamping and/or relamping
	Improve janitorial workflow to consolidate activities in each area, allowing a reduction in operating hours for lighting
	Verify or establish an effective maintenance protocol for the refrigeration system, and for cooking equipment in kitchen areas and break rooms, including cleaning evaporator and condenser coils, exhaust vents, and burners
	Ensure that air flows in refrigerated cases are not blocked by improperly stocked shelves

Table D–1 Prioritization of EBCx Measures (cont'd)

Priority	EEM Description
2. Important measures that should be considered for all projects (discussed in this guide)	Weatherstrip/caulk windows and doors where drafts can be felt
	Reduce set point for domestic hot water to 120°F, with boost heating for dishwashers
	Install low flow aerators on faucets
	Disable circulation pumps when building is unoccupied
	Verify or establish a comprehensive maintenance protocol for HVAC equipment, including cleaning cooling and heating coils, burners, and radiators
	Clean and/or replace air, water, and lubricant filters
	Utilize timers for compressors and turn off lights on vending machines
	Ensure correct refrigerant charge in cooling systems and heat pumps, and repair any refrigerant leaks
	Provide power strips in easy to access locations to facilitate equipment shut-down
	Re-optimize SAT reset based on current building loads and usage patterns
	Verify adequate deadband between heating and cooling
	Move improperly located thermostats to prevent over- or under-cooling/heating
	Optimize equipment staging/sequence of operation
	Apply standby mode to registers when not in use; turn registers off when store is closed
	Update and maintain a Systems Manual with O&M requirements
	Test and adjust ventilation flow rates as needed to meet ASHRAE 62.1 requirements
3. Additional measures that should be considered in certain situations (mentioned in this guide)	Clean lamps, fixtures, and diffusers
	Activate any disabled controls if the reason for disabling can be addressed or if there no reason for disabling is evident
	Improve sensor locations/move line-of-sight obstacles
	Calibrate cooking equipment temperature settings, repair broken knobs, and ensure pilot light is not overlit
	Turn off refrigerator door heaters
	Insulate refrigeration lines and ensure adequate shading of remote condensers
	Auto closers on walk ins and reach ins
	Load cold items into refrigerated cases quickly after received
	Repair broken windows
	Repair pipe and tank insulation
	Align/tighten belts and pulleys
	Post the correct operating parameters near each piece of equipment
	Turn off unneeded heating/cooling equipment during off-seasons
	Re-optimize chilled water temperature reset based on current building loads and usage patterns
	Re-optimize condenser temperature reset based on current building loads and usage patterns
	Calibrate time clocks

Table D–1 Prioritization of EBCx Measures (cont'd)

Priority	EEM Description
3. Additional measures that should be considered in certain situations (mentioned in this guide)	Optimize equipment start/stop procedures
	Seal leaky ducts
	Replace or repair leaky and broken dampers
	Verify that exhaust air is released outside the building, not the attic
4. Lower priority measures considered less likely to be cost effective or to save a significant amount of energy in most grocery stores (not addressed in this guide)	Verify correct superheat setting on all TXVs
	Repair any leaky pipes and fixtures
	Flush boiler system to remove sediment
	Inspect oven door seals and hinges and repair if necessary
	Group cooking equipment with similar ventilation requirements (Type 1 or 2, light or heavy duty, condensing or heat/fume hood), provide only the ventilation rate needed, and align equipment with hood exhausts
	Check electrical connections and clean terminals
	If the store has an attic, make sure the vents are open and clear of debris
	Cap unused air chases
	Check flue gas temperature and concentrations for furnaces, and adjust combustion airflow if necessary
	Check lubricant levels, pressures, and colors, refilling/replacing as needed
	Repair leaky pipes, valves, and fittings
	Correct motor shaft misalignments
	Secure motor, compressor, and fan mountings to prevent vibration
	Implement optimized control of VAV supply fan, based on furthest open VAV damper

Table D–2 Prioritization of Retrofit Measures

Priority	EEM Description
1. Recommended in all example packages	Replace incandescent ambient lighting with CFL and accent/display lighting with ceramic metal halide
	Replace refrigerated display case lighting with LEDs
	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient
	Install high efficiency ECM evaporator fans
	Install strip curtains and weather seal walk-in freezer doors
	Install VSD kitchen hood exhaust fans with DCV
	Replace inefficient motors with right-sized NEMA premium efficiency
	Convert constant volume or dual duct air handling systems to VAV
	Upgrade to DCV to reduce outdoor airflow during partial occupancy
2. Recommended in some example packages	Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts
	Replace kitchen/deli/bakery appliances with ENERGYSTAR models
	Add reflective roof covering
	Install doors on open refrigerated cases

Table D–2 Prioritization of EBCx Measures (cont'd)

Priority	EEM Description
3. Important measures that should be considered for all projects (discussed in this guide)	Install wireless motion sensors for lighting in rooms that are used intermittently (break rooms, storage areas), and for lighting in refrigerated display cases
	Increase the availability of daylight through the addition of skylights, tubular daylighting devices, or hybrid solar lighting that collects and distributes sunlight via optical fibers to the building interior
	Install timer controls for non-essential lighting when building is unoccupied
	Replace metal halide exterior lighting with LED for façades and parking lots, with photocell control
	Install evaporative condensers for refrigeration systems
	Replace commercial refrigerators, freezers, and ice makers with ENERGY STAR models
	Install walk-in freezer alarms and automatic door closers to reduce time when doors are left open.
	Replace electric resistance furnaces with water source heat pumps
	Install an EMS to control, track, and report energy use
	Upgrade electronic controls
	Install a dry-bulb air-side economizer (differential enthalpy in humid climates)
	Install a desiccant wheel dehumidification system
	Add refrigeration system heat recovery coils for hot water or space heating
	Install night curtains to reduce load on open refrigerated cases
	Install VSDs on condenser fans for the refrigeration system
	Install compressor unloaders for capacity control
	Install controls to disable ASHs when dew point is low
	Install smart defrost controller in walk-in freezers and low-temperature cases
	Add energy recovery to ventilation system
	Install VSDs for ventilation fans and adjust the ventilation rates as needed to meet ASHRAE 62.1 recommendations
4. Additional measures that should be considered in certain situations (mentioned in this guide)	Replace standard T-8 fluorescent lamps with high-efficiency T-8
	Install specular reflectors and de-lamp
	Replace lighting system with a more efficient approach (reduced ambient light, greater use of accent lighting, indirect T-5 fixtures in place of direct T-12 fixtures)
	Institute a "green purchasing" policy (replacement with ENERGY STAR at end of useful life)
	Replace electrical transformers with right sized, higher efficiency models
	Install make-up air units and heat recovery system for kitchen exhaust hoods
	Replace hot food holding cabinets with insulated, doored holding cabinets
	Mechanical subcooling in refrigerated cases
	Replace standard low-temperature reach-in and coffin cases with more efficient doored reach-in cases
	Replace medium temperature open cases with high-efficiency doored cases

Table D–2 Prioritization of Retrofit Measures (cont'd)

Priority	EEM Description
4. Additional measures that should be considered in certain situations (mentioned in this guide)	Add heat recovery from refrigeration process and kitchen drain water to pre-heat service hot water
	Implement floating head pressure and floating suction pressure controls
	Add continuous roof insulation
	Install vestibules with inner and outer doors
	Replace windows and frames with double paned low-e, vinyl-framed windows
	Install low flow pre-rinse spray valves in kitchen
	Install VSDs on hot water pumps
	Install high-efficiency condensing water heater
	Add insulation to steam/hot water pipes
	Add evaporative pre-cooling of supply air (in dry climates only)
	Supplement DX cooling system with an indirect evaporative cooler sized to meet small and medium cooling loads (in dry climates only)
	Replace DX cooling system with more efficient right-sized model with evaporative condenser and enhanced dehumidification
	Install DOAS with high-efficiency heat recovery, reducing the heating, cooling, and dehumidification loads
	Replace air- or water-cooled heat pump with a right-sized ground source heat pump
	Implement "dual maximums" control strategies for VAV terminals
	Install a coil bypass to reduce pressure drop when there is no call for heating or cooling
	Install pleated or angled filters to reduce pressure drop
5. Lower priority measures considered less likely to be cost effective or to save a significant amount of energy in most grocery stores (not addressed in this guide)	Modify window areas/locations to optimize daylighting
	Replace exit signs and channel signs identifying departments with LED versions
	Replace mercury vapor with metal halide
	Install LEDs in all downlights
	Replace broken and yellowed diffusers, and de-lamp if possible
	Install photosensors to turn off lights when daylighting is sufficient
	Replace T-12 lamps with T-5 fluorescent lamps
	Change gas defrost systems to electric defrost, when possible during major equipment replacement
	Add insulation to water heaters and pipes
	Install automatic shutoff controls for sinks
	Install water heater temperature setback controls
	Drill and fill insulation in exterior wood-framed walls
	Install solar control window films
	Add rigid insulation to basement walls
	Install VSDs on chilled-water and hot water pumps
	Install VSDs on cooling tower fans

Table D–2 Prioritization of Retrofit Measures (cont'd)

Priority	EEM Description
5. Lower priority measures considered less likely to be cost effective or to save a significant amount of energy in most grocery stores (not addressed in this guide)	Add a VSD on the chiller compressor
	Reduce excess combustion air by installing a combustion monitoring and trim control system
	Add controls to stage chillers to operate closer to full capacity
	Add duct insulation
	Upgrade to cogged or synchronous belts
	Install direct drive motors on roof exhaust fans, eliminating fan belts
	Install electronic evaporator pressure regulators or TXVs, where possible
	Create distributed refrigeration system
	Add ambient sub-cooling
	Replace storage water heaters with high efficiency condensing tankless
	Install solar hot water pre-heat
	Add insulating sheathing to exterior walls
	Install overhangs above south-facing windows
	Add slab insulation
	Replace air cooled chiller with high efficiency, right-sized water-cooled chiller
	Replace the HVAC system with variable refrigerant flow system
	Install chilled beam cooling system
	Install radiant cooling system.
	Replace air-cooled chiller with high efficiency, right-sized air-cooled chiller
	Install a ground-couple central chilled-water plant (central geothermal system)
	Install more efficient right-sized condenser
	Increase numbers of staged compressors

Appendix E

Detailed EBCx Measure Descriptions

E.1 Lighting

E.1.1 Calibrate any existing lighting controls and optimize settings based on building usage patterns and daylight availability

Grocery stores may use a variety of strategies and technologies to provide automatic control of light levels. Control may be based on time-of-day, occupancy, and existing light levels. Even if these controls were properly installed and commissioned to begin with, they may have drifted away from their optimum settings, they may have been tampered with by store personnel, or conditions may have changed, requiring new settings. For example, if lighting is automatically turned on or off based on business hours and maintenance schedules, and those schedules change, then the set points will have to be changed.

If a store makes use of daylight harvesting, in which electric lighting levels are adjusted up or down based on the amount of daylight present, the photo sensors in the system may need to recalibrated—that's especially true if the layout or use of the space has changed, leading to different levels of reflectivity in the vicinity of the sensors.

The effectiveness of lights controlled by occupancy or motion sensors depends on setting the right sensitivity and time-delay for particular spaces. In addition, correct positioning of the sensor will help to optimize coverage of the occupied area. If the store has been remodeled or furnishings have moved so that the sensors are obstructed, the sensors should be relocated. For details on settings and positioning of occupancy sensors, see the EPA's *Building Upgrade Manual,* Chapter 6.

Checking these controls and their associated sensors will ensure that the proper light levels are maintained for customer satisfaction and product display while cutting energy bills for the store. The savings that can be achieved by tuning lighting controls will depend on how extensively controls are used and how poorly they have been maintained. Problems with lighting controls are fairly common. For example, one study of daylight harvesting systems in more than 100 buildings of various types found that the systems often do not provide the expected energy savings (Vaidya et al 2004). Another study found a high failure rate among the connectors in lighting control wiring (DOE 2002).

E.1.2 For fixtures with one or more burned out lamps, replace all lamps with lower wattage versions that produce equivalent or superior light output and quality

Many grocery stores depend on 32-W 4-foot T-8 (32 W T-8) linear fluorescent lamps to illuminate their stores. Older 32-W T-8 lamps can be replaced with reduced wattage lamps (30-W, 28-W and 25-W versions are available) with little or no loss in light output, and without any other modifications necessary. For example, a standard, commodity grade 32-W T-8 lamp provides a nominal 2,800–2,850 initial lumens (lm). A high-performance 30-W lamp provides 2,850 lm, while a 28-W lamp puts out 2,725 lm. This approach will not work if the facility already uses high-performance T-8s, which provide an initial 3,100 lm unless the facility is overlit. Make sure that the new lamp is compatible with the existing ballast; and if you're replacing lamps in just one fixture, make sure the color matches the lamps in other fixtures.

E.1.3 Adjust light levels to within 10% of the IES recommendations for the tasks conducted in each area by delamping and/or relamping

Sometimes stores, or areas within a store, are overlit. In such cases existing lamps can be replaced with lower wattage lamps, as described above, or lamps can be removed from fixtures with multiple lamps. To carry out the process, measure existing light levels, compare them to recommendations from the Illuminating Engineering Society, identify areas that are overlit, and consider removing lamps in those areas. If removing a lamp will decrease output by too much, installing a reflector can make up the difference. It's also possible to reduce lighting energy by replacing all existing lamps with a smaller number of high-performance lamps. Mark fixtures where lamps have been removed so that the lamps are not replaced by unwary maintenance staff. Afterwards, make sure that light levels are still adequate, and that the light distribution is satisfactory. Part of the process can include cleaning lenses on fixtures, which will also increase light output. Light levels and energy use can also be decreased by replacing existing ballasts with units that have a lower ballast factor.

E.1.4 Improve janitorial workflow to consolidate activities in each area, allowing a reduction in operating hours for lighting

Revised janitorial practices, such as implementing team cleaning, revising hours, and coordinating with security, help to reduce the operating time of lighting systems and cut electricity use in stores. Team cleaning confines janitors to a specific area, focusing on their different tasks. When they complete their job in that area, they can shut off lights and move on to the next. Scheduling janitorial tasks for daylight hours, where possible, means those tasks can be performed without keeping lights on longer than necessary. Janitors can coordinate with the security crew to walk through the building and turn off equipment left on. The Building Owners and Managers Association's (BOMA) Building Energy Efficiency Program (BEEP) reports that implementing these strategies can produce 0.6%–8% energy savings per year in commercial buildings (Lord 2008).

However, there can be difficulties in transitioning to team cleaning. Many long time traditional zone cleaning janitorial employees are unwilling to change their ways, and some labor unions see any attempts to institute team cleaning as a potential reduction in work hours. In addition, the transition to team cleaning requires a training and implementation plan to ensure quality and avoid confusion and lack of communication between janitorial staff (Meyers 2003).

E.2 Plug and Process Loads

E.2.1 Control computer power management settings facility wide through software or logon scripts, ensuring settings can't be overridden

Ensuring that appropriate power-management settings are set for all non-critical computers and servers, through a centrally managed network, can significantly reduce electricity consumption. The EPA provides a *Computer Power Management Savings Calculator* that estimates potential energy savings from the use of ENERGY STAR computers and power management settings.

If your store or corporation uses a Windows-based network, a network administrator can develop and deploy group policy objects or log-on scripts that control power management settings from the server level. This approach prevents users from changing settings and allows flexibility to create groups of users with similar computing habits to accommodate different operating needs. When implemented properly, group policy objects and log-on scripts can be a cost-effective strategy because they ensure that power management settings will be enabled and maintained at the appropriate level for each user without the need to purchase additional software. The EPA offers EZ GPO, a free tool to assist network administrators in creating group policy objects.

If your facility has multiple types of hardware and operating systems on the same network, power management software is a good solution. Software is installed on each computer and centrally controlled through the internet or store network. Depending on the program used, IT staff can manually wake up computers for maintenance, monitor energy consumption and savings, and apply different settings to different groups of computers. These programs generally run from $10 to $20 per computer and are often available at discounted rates for bulk purchases. With average annual savings ranging from $25 to $75 per machine, the payback period is typically less than a year for a desktop computer (E Source 2010).

Several technical challenges might deter implementation of facility-wide power management settings. Some stores may not have the IT staff capability to install third party power management software. In addition, depending on the software, there can be concern about how to ensure that sleeping computers receive critical administrative software updates, such as security patches and antivirus updates. The EPA provides technical consultations to answer questions about the various options for keeping sleeping computers up to date with security and other software patches while running its free software tool.

E.2.2 Utilize timers for compressors and turn off lights on vending machines

Refrigerated vending machines often operate 24 hours per day, seven days a week. In addition to consuming more than 3,000 kWh per year of electricity, they add to cooling loads in the spaces they occupy. At $0.10/kWh, annual operating costs typically exceed $300 (Sanchez et al 2007). Timers or occupancy sensors can yield significant savings because they allow the machines to turn on only when a customer is present or when the compressor must run to maintain the product at the desired temperature. Some vending machine suppliers will install a timer for free, if asked. At least one device now on the market uses a passive infrared occupancy sensor to turn off the compressor and fluorescent lights in the vending machine when no one is around; a temperature sensor will power up the machine only as needed to keep products cool. Typical energy savings from occupancy-sensor based systems run about 20%–40% at a cost of about $90 per machine (NPCC 2007). An independent study also found that these types of system could reduce maintenance costs by reducing compressor cycling (Foster Miller 2002).

Deactivating the fluorescent lamps that typically illuminate a vending machine can also save energy—990 kWh/yr according to one study. Vending machines built before 2002 typically use T-12 fluorescent lighting and could save 385 kWh/yr through an upgrade to T-8 lighting. However in most cases that kind of retrofit cannot be done in the field (NPCC 2007).

E.2.3 Provide power strips in easy to access locations to facilitate equipment shutdown

Grocery stores use a variety of plug-in devices such as printers, fax machines, computers, and copiers. Even when turned off, this equipment uses a small amount of "phantom" electricity. Using power strips for computers and peripheral equipment allows the power supply to be completely disconnected from the power source, eliminating this standby power consumption. Easily accessible power strips allow quick shut-down of multiple pieces of equipment at once. "Smart" power strips with built-in occupancy sensors, built-in logic that senses when attached devices are idle, or timers, can shut off printers and copiers when no users are present.

Some power strips have combination outlets, with certain outlets featuring automatic shutoff functions while others continuously supply electricity. This enables equipment, such as fax machines, that need to remain on when idle, to be plugged into the same power strip as other equipment that can be shut off, such as copy machines.

The actual level of savings achieved using power strips depends on such factors as the control strategy employed, the type and number of appliances connected to the strip, and the existing usage patterns. In the right applications, smart power strips can be very cost effective—often with simple payback periods of less than two years.

To estimate the level of energy savings multiply the difference in power draw between the fully off and idle modes (for all attached equipment) by the amount of time that the attached equipment is likely to be turned off. To obtain estimates of standby power draw for different types of equipment, see the TIAX report entitled "*Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type*," which includes measured data for a wide range of devices (McKenney et al. 2010). Because the amount of time any equipment will be turned off by the strip is dependent on the specific control technology used and the consumer's usage patterns, it generally needs to be estimated on a case-by-case basis (E Source 2011).

E.2.4 Apply standby mode to registers when not in use; turn registers off when store is closed

Grocery stores depend on cash registers to record sales and track inventory. Many stores install a high number of registers to handle the largest crowds, but most often these stores are only operating a fraction of the registers. A report on the ergonomics of cash registers observed 15 different supermarkets, finding an average of 9.4 registers per store, with the number ranging from 4 to 20 registers (Shinnar et al, 2004). If these registers are being left on when they're not in use, they are wasting energy.

According to an NREL report on plug and process loads, the average cash register uses 50–80 W. If that register also uses peripheral components such as a demagnetizer, barcode scanner, scale, or conveyor belt, the total energy use can be 75–130 W. Most registers have a standby mode which can save as much as 50% of the energy used in active mode (NREL 2011). Store managers should make sure that the standby mode is enabled for each cash register and should train those employees that regularly operate the cash registers on the energy impact of this action.

Considering the long hours most supermarkets are open, simply putting unused cash registers in standby mode or turning them off completely can return substantial savings. For example, consider a supermarket with 10 cash registers that draw 100 W each with components. Under the worst case scenario, none of these registers are ever turned off, adding up to 8,760 kWh annually. Now assume the registers are only turned off at night (eight hours, store closed from 10 pm to 6 am): this measure will save 2,890 kWh, or 33%. The pattern is clear: the longer each register is in standby mode or turned off, the more energy is saved.

E.2.5 Obtain lower electricity rates (where available) by allowing the utility to disable non-essential equipment during peak load periods or by participating in a demand response program

Utilities experience periods of high demand for electrical power—high enough at times that it threatens to disrupt service in the utility's service territory. One way some utilities are combating this problem is by offering lower rates, discounts, credits, and other cost-saving methods to customers that agree to voluntarily reduce their electricity when requested, or allow the utility to disable non-essential equipment during these peak load periods—typically in the afternoon. Pathmark Stores, a leading east coast chain, participates in a demand response program by turning off half of its lights when requested by the utility (EnerNOC 2005).

The Federal Energy Management Program (FEMP) has a *website listing energy incentive programs* offered throughout the United States. By clicking on a specific state in this map, a new page will open listing all incentive programs offered in that state. This will include any utility programs offering discounts and credits for those customers willing to give the utility the capability to turn off equipment during peak periods.

E.2.6 Schedule cooking activities to use equipment at full capacity

Cooking equipment is often left running when it's not in use so that it will be ready to go whenever it is needed. However, if cooking activities are scheduled properly, the equipment can be turned off when not in use and turned on in time to be ready for its next use. In addition, tasks can be scheduled so that the equipment is running at full capacity—cooking appliances are more efficient when they're cooking food at full capacity (Fisher 2002). In addition, if equipment is run only when it is at full load, it can be shut down for longer periods of time. The energy that can be saved by turning off idle equipment varies with the practices in a particular kitchen, but Table E–1 presents some typical numbers.

Table E–1 Potential Energy Savings From Turning Off Unused Kitchen Equipment

	Annual Savings Possible*	
Turning off unused gas burners	100 therms	$100
Turning off unused electric burners	1,000 kWh	$90
Turning off gas underfired broiler, 1 hour per day	360 therms	$370
Turning off electric broiler, 1 hour per day	3,600 kWh	$310

Credit: E Source

*Energy rates used are $1.037/therm and $0.087/kWh.

E.2.7 Verify that airflow paths around transformers are not blocked

The location of all non-pole-mounted transformers will be determined by local codes and building designers. Depending on where a transformer is located on the property, it's possible that personnel will stack boxes, crates, pallets, trash or other items around the transformer. This action can block the airflow to the transformer, which in turn can lead to overheating and a reduction in efficiency. While the transformer layout typically includes some kind of physical barrier to prevent public access to the transformer, it is still the responsibility of store management to make sure that the area around each transformer is kept clear. Most codes will also require that transformers be readily available for inspection and maintenance; thus management should consider adding a visual inspection of the transformer area to regularly scheduled maintenance.

E.2.8 Verify balanced three-phase power and proper voltage levels

In a three-phase electrical system, the voltage of each phase should be symmetrical, have equal magnitude, and be separated by 120 degrees. Phase imbalance of 5% or less is usually acceptable, although motor manufacturers and other electrical equipment sometimes require a smaller phase imbalance to prevent voiding the warranty. As the phase imbalance increases, electrical equipment will overheat, reducing efficiency and eventually leading to equipment malfunction. If the power coming in is unbalanced, there are two methods to minimize the voltage imbalance: balance the three single-phase loads equally, and separate any single-phase loads that disrupt the load balance by feeding them from another line.

Improper voltage levels can have the same effect on electrical equipment. Operating equipment at voltages higher or lower than the equipment rating will lead to excessive heat and shorten the equipment's useful life. To avoid this occurrence, make sure that the proper electrical equipment is selected based on average load ratings rather than maximum loads.

Maintenance staff should inspect voltage levels and phase balance annually as part of regularly scheduled maintenance. More frequent inspections should be performed if certain electrical equipment is consistently shorting out or failing.

E.3 Refrigeration

E.3.1 Ensure that open refrigerated cases are covered when store is closed

Night covers, also known as night curtains, feature a roll of woven aluminum or plastic at the top of an open refrigerated display case. When a store closes for the night, employees simply pull the down the curtain to stop the leakage of cool air from the case to the warmer surroundings. A study by the Southern California Edison Refrigeration Technology and Test Center found that using night covers cut the daily cooling load by 12.6% and total energy use by 9.0%. The test assumed that the supermarket used the covers for six hours a day (from midnight to 6 am). Researchers also observed that the cases remain colder for a longer period of time after the cover is removed, which in turn lengthens product shelf life (SCE 1997). Aluminum or aluminum-coated covers yield the greatest energy savings because aluminum boasts a low emissivity. Plastic or vinyl covers are less effective. Also, the longer a store is open, the smaller the savings will be—a store open 24 hours a day will not benefit from a night cover.

E.3.2 Raise set points in refrigerated cases when possible

The lower the set point of a refrigerated case, the more energy the system consumes. ENERGY STAR recommends that freezers operate between –14° and –8°F, and refrigerators operate between 35° and 38°F. If freezers or refrigerated cases are operating at temperatures lower than these ranges, adjust them to be within the recommended temperature range. Staff should check the temperature of perishable items after any changes are made to case temperature set points to ensure that they are within the safe range. The U.S. Food and Drug Administration (FDA) requires the core temperature of perishable items stocked in refrigerated cases to be at or below 41°F at all times (FDA 2009).

E.3.3 Clean and calibrate humidity sensors that control anti-sweat heaters

Many refrigerated display cases have ASHs, which heat the door to prevent condensation when it is opened. Controls are available to monitor the temperature or humidity of the store and run the heater only when there is a risk of condensation, which decreases the runtime. By decreasing the operational time of the heaters, not only do the heaters themselves use less energy, but the amount of heat they add to the refrigerated case is also decreased. However, the sensors in these systems need periodic cleaning and recalibration to maintain their accuracy. If the sensors drift the heaters could run longer than necessary and increase energy use.

E.3.4 Repair/replace gaskets and seals on refrigerated cases

A gasket is a flexible elastic strip attached to the outer edge of a refrigerator or freezer case that is designed to form an airtight seal between the cold interior and warm exterior. Damaged and cracked gaskets and seals result in air leakage and energy loss. Gaskets and seals should be checked on a quarterly basis for signs of degradation and replaced when necessary. Signs of worn seals and gaskets include cracking, small side tears, and loosening of the adhesive bond.

E.3.5 Verify correct charge in refrigeration systems, and repair any refrigerant leaks

As refrigerant leaks out of a refrigerated system, the system becomes under-charged, which has several consequences. The load on the compressor increases, causing it to run for longer periods of time; suction and head pressures decrease; and ultimately there is an inability to maintain required temperatures within freezers and refrigerated cases. Low or incorrect refrigerant levels can reduce efficiency by 5%–20% (EPA 2008). Any refrigerant leaks should be repaired immediately and the system charge should be checked on a monthly or quarterly basis in order to maintain the correct charge and detect any leaks.

E.3.6 Verify optimal head and suction pressures

The refrigeration system's compressor rack is often the largest energy user in any supermarket (Better Bricks 2008), but even smaller and medium-sized stores with stand-alone compressors can benefit from verifying compressor pressures and keeping them at optimal set points. Set head pressure (pressure of the refrigerant discharged from the compressor) using the manufacturer's recommendation for pressures based on refrigerant type and desired temperature (this will usually be provided by the manufacturer in the form of a chart). Operating the compressor above the recommended head pressure will waste energy. You may find that you can lower the head pressure and still achieve proper product temperatures, but lower the pressure in small increments. All systems may not be able to meet cooling demands at lower head pressures, so closely monitor how the system performs when adjusting head pressures. It may be prudent to have a certified refrigeration technician conduct pressure adjustments, particularly if lowering the pressure beyond the pressure setting that correlates to 70°F.

The suction pressure is determined by the head pressure and the flow-metering devices between the condenser outlet and evaporator inlet, and with one exception, there is no independent adjustment that can be made to reduce energy use. A TXV, which is a common flow-metering device, controls the amount of refrigerant entering the evaporator by sensing the load across the evaporator and adjusting the flow accordingly. TXVs do this by measuring the temperature difference at the evaporator inlet and outlet. The TXV also acts as a safety measure, ensuring that no refrigerant in the liquid state returns to the compressor. Because TXVs are very stable, they will typically not require any adjustment. Having a technician check the superheat can confirm proper TXV operation or identify if a TXV is operating outside of its designed conditions. Once the head pressure is set and superheat confirmed, the suction pressure will fall in line. However, in the case of larger rack systems, the refrigerated cases may have an evaporator pressure regulating (EPR) valve. This valve is used to keep the case evaporator pressure from falling too low. If the load has been reduced on the refrigerated case, through other retro-commissioning or retrofit measures, then this minimum EPR setpoint can probably be raised, which can reduce the pressure drop across the compressor and reduce its power consumption. Again, this adjustment is probably best handled by a certified refrigeration technician.

E.3.7 Verify or establish an effective operations and maintenance protocol for the refrigeration system, and for cooking equipment in kitchen areas and break rooms, including cleaning evaporator and condenser coils, exhaust vents, and burners

Maintaining clean vents, coils, and burners helps to ensure that refrigeration and cooking equipment run efficiently; and scheduling can significantly reduce kitchen energy use. According to Pacific Gas and Electric's Food Service Technology Center, the commercial food sector wastes up to 80% of the energy that is purchased (DOE 2009a). Simply reducing the amount of operating time of cooking equipment in a supermarket kitchen area can reduce energy use by up to 60% (ASE 2004). For example, there is no need to preheat ovens for longer than 15 minutes, and oven fans and vent hoods should only be used when necessary to maintain comfort and air quality. In addition, appliances such as warmers and mixers should only be turned on as needed. Keeping refrigeration system coils and filters clean and free of obstructions will improve their efficiency. Staff training will help to encourage efficient practices. Training should cover equipment maintenance, operational schedules and set points, start up and shutdown procedures, and emergency procedures.

E.3.8 Ensure that airflows in refrigerated cases are not blocked by improperly stocked shelves

Open refrigerated cases use a continuous flow of cold air, often referred to as an air curtain, to keep certain products such as meats and dairy goods at safe temperatures. This cold air flows from the top of the case and, due to its higher density, drops down the open front of the case, blowing across the products in the process. The air is then drawn into the bottom of the case by circulation fans, where it is cooled again and sent back to the top of the case.

In order for this process to work effectively, the air return at the bottom of the case must be kept clear. Improperly stocked items or labels blocking the air return vent will cause cold air to spill out of the case and let warm air enter, increasing the cooling load. To prevent this occurrence, assign staff to ensure that refrigerated cases are stocked properly, labels and price tags are located correctly, and that nothing obstructs the air return at the bottom of the cases.

E.4 Building Enclosure

E.4.1 Weatherstrip/caulk windows and doors where drafts can be felt

Windows are an important part of the building envelope, which is critical for controlling infiltration, convection, radiation, and conduction (Figure E–1). Windows that do not close tightly, have cracks, or are not weatherized, allow escape of conditioned air and the influx of extra air that needs to be conditioned, thus increasing the demand on the heating and cooling systems. Water leaks through windows are also a concern in stores because of the potential for mold growth and compromising IAQ. Leaky windows should be repaired with caulking and weather-stripping, and cracked glass should be replaced. Compressor rooms should be made as airtight as possible. Caulking and weather stripping are lower cost measures that can have a one-year payback from savings associated with the decreased demand on the HVAC system (Efficient Windows Collaborative 2011).

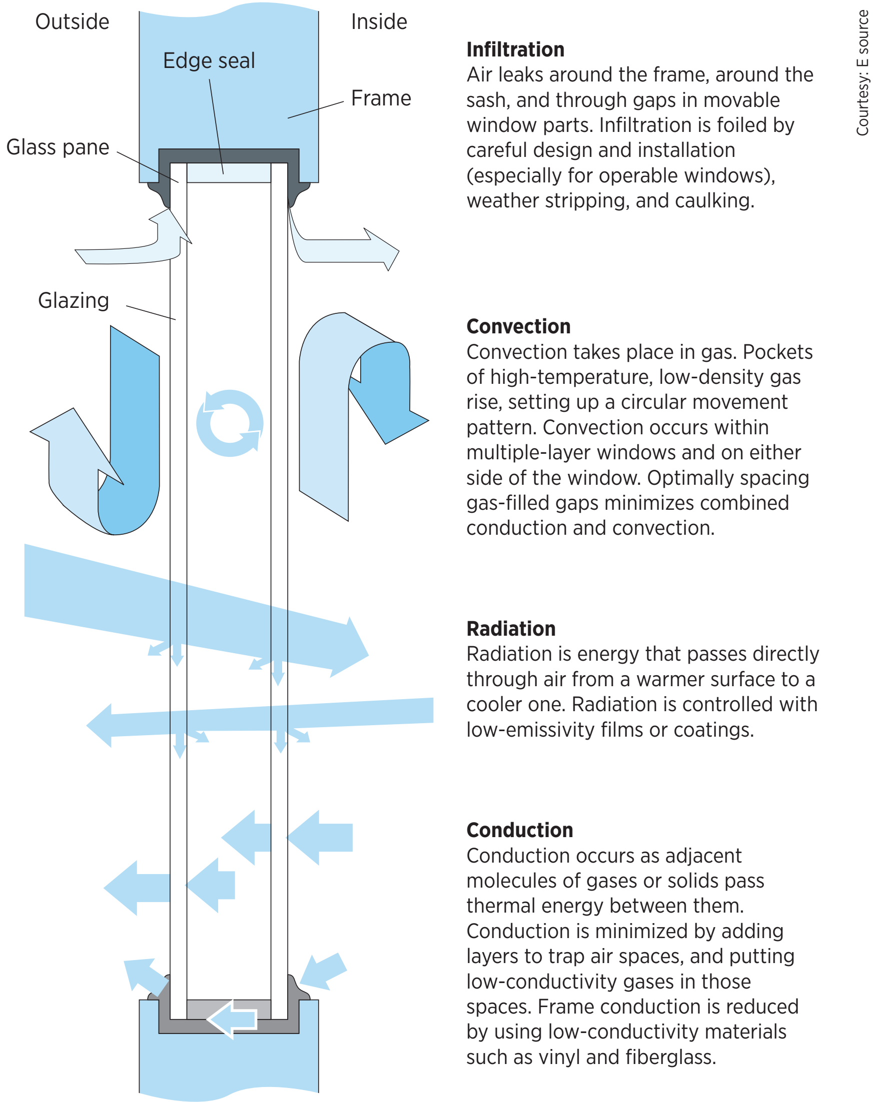

Figure E–1 Windows exchange energy with the environment through a combination of convection, conduction, radiation, and air infiltration

E.5 Service Water Heating

E.5.1 Reduce set point for domestic hot water to 120°F, with boost heating for dishwashers and other cleaning or sanitizing operations

Setting the temperature for a storage water heater at 120°F will be sufficient for the majority of uses for hot water—such as employees washing their hands and most cleaning activities. However, other tasks require water to be at a higher temperature; for example, dishwashers generally use water at 140°F for cleaning with detergents or 155°F for sanitizing cycles.

If the storage water heater supplying hot water to the dishwashers is set higher than 120°F, turn it back down to 120°F. All modern dishwashers have internal boost heaters to raise the dishwasher water temperature to 140°F. Most dishwasher manufacturers do not allow this booster heater to be disabled because doing so can compromise the quality of the dishwashing. And by turning the temperature set point down on the storage water heater, the store is saving energy. Every 10°F reduction in the water heater temperature setpoint below 140°F saves about 3% of water heater energy use (Hoak et al 2008).

E.5.2 Install low-flow aerators on faucets

Low-flow aerators save energy as well as water—less water used means less water has to be heated and less pump energy is required. While there is no standard value for typical "low-flow" rates, most defer to values from the EPA *Water Sense* program, designed to improve water efficiency and protect the U.S. water supply. Part of the program includes the Water Sense label, awarded to products that "use less water while performing as well as or better than conventional models." Water Sense faucets must have a flow rate of less than 1.5 gallons per minute (gpm). In comparison, federal regulations mandate that new faucet flow rates be less than 2.5 gpm at 80 pounds per square inch (psi) of water pressure and less than 2.2 gpm at 60 psi.

To calculate energy savings from low-flow faucets, FEMP offers an *online energy cost calculator*. The calculator allows a comparison of a specific product to baseline models as well as other more efficient products. The calculator uses the following values for energy use per gallon of water: 0.05 kWh/gal and 0.003 therms/gal. Actual energy savings will vary depending on usage and local utility rates, which can be entered into the FEMP calculator.

E.5.3 Disable circulation pumps when building is unoccupied

Water heating systems typically use a circulation pump to distribute hot water to points of use. Unless these pumps have a timer or on-board controls that can reduce or shut off the pumping operation when water is not flowing, they will run 24 hours a day, 365 days a year. The potential for energy-savings in this scenario is large. A 2010 report from PNNL evaluated the potential savings from shutting down a 45-hp circulation pump during unoccupied periods. The pump originally operated 24 hours per day, every day of the year, costing over $26,000 annually for electricity. By reducing the number of days the pump operated to 250 days (disabling it on weekends and holidays), they projected savings of 32%, or over $8,000. By further reducing the operation to 12 hours per day for 250 days, the

In a report for the Food Service Technology Center, a casual dining restaurant tested a new high-efficiency gas-fired hot water system with an optimized schedule for the circulation pump. Compared to the existing system which operated the circulation pump 24 hours a day, the new system setup was projected to save over $1,700 annually. A portion of the savings came from the high-efficiency hot water heater, but savings also came from shutting the circulation pump off for 10 hours every day (Wallace and Fisher 2007).

report projected savings of 66%, or over $17,000 (Hatley and Goddard 2010). Actual savings will vary with the size and number of circulation pumps in operation, and for grocery stores, the potential reduction in operating hours for the pump may be significantly less than the study indicates.

Before any circulation pumps are disabled, confirm that all hot water pipes are located in conditioned space. If hot water circulation is turned off, any pipes exposed to unconditioned air below freezing are susceptible to freezing and bursting.

E.6 HVAC: Heating and Cooling

E.6.1 Test, adjust, and balance (TAB) valves and refrigerant lines to ensure that supply air temperatures meet cooling loads and no unnecessary flow restrictions are present

As buildings age, so do their internal systems. Equipment slowly degrades, occupants alter system setpoints away from ideal settings, and cooling loads fluctuate as occupancy levels and space usage within a grocery store change. This aging process can lead to inadequate cooling in occupied spaces, hot- and cold-spots, and equipment overloading. TAB is conducted to bring the cooling system back into balance and maximize equipment life and occupant comfort while minimizing wasted energy.

The TAB process involves testing equipment functionality and making improvements and repairs as needed, adjusting system parameters, and balancing them to efficiently meet building loads and satisfy local ordinances. Equipment problems such as improper fan speeds, chipped fan blades, and incorrect refrigerant charge are also revealed through TAB.

TAB may be needed if building staff are constantly adjusting HVAC components to maintain comfort, occupants are frequently submitting complaints regarding indoor comfort issues, or spaces within the building have been repurposed. TAB analysis should also be conducted as part of any major renovation and recommissioning efforts. A balanced system can fall out of "tune" in a year or two with constant use, so rebalancing every few years keeps HVAC systems operating efficiently. While savings through TAB are hard to generalize because they depend heavily on existing building conditions, improper operations from the cooling system will eventually lead to occupant discomfort and/or wasted energy.

E.6.2 Verify or establish a comprehensive maintenance protocol for HVAC equipment, including cleaning cooling and heating coils, burners, and radiators

While EBCx will identify all major HVAC equipment problems and necessary repairs, establishing maintenance schedules and procedures ensures that efficient operations of the HVAC system will continue, and will lengthen the useful life of the system and its individual components.

An important step in this process is acquiring or creating reference maintenance materials for all HVAC equipment and systems. These include product literature and service manuals from the manufacturer as well as maintenance logs to record all maintenance activities. With these documents in place, establish preventative maintenance schedules for each component of the HVAC system. Each element within the HVAC system will have its own list of scheduled maintenance items to be carried out by building staff.

The idea behind scheduling preventive maintenance measures is to avoid major system failures. The preventive method gives building staff an opportunity to evaluate HVAC systems regularly, identifying potential problems before they become major operational problems. These schedules will also drive procurement schedules, ensuring that replacement parts are available when they are needed.

Important elements in the process include: condenser and evaporator coils, burners, and radiators.

Coils. To maintain efficiency in a vapor compression cooling system, it is important to keep condenser and evaporator coils clean. Dirt on the evaporator coil reduces system airflow, and degrades the coil's heat-transfer efficiency, which in turn cuts cooling capacity. Inspect the evaporator coil at least annually to ensure that the filters are doing their job. Shining a light through the coil is one way to inspect it, although enhanced fin designs, with their wavy patterns can make this difficult. An alternative is to measure supply-fan current and filter/coil pressure drop with clean filters in place. If the pressure drop is higher than last year's measurement, then the coil is dirty and needs to be cleaned. For single-speed fans with PSC motors, the current will drop when the coil is dirty. For variable speed fans, current will go up.

Unlike the evaporator coil, the condenser coil sees unfiltered outdoor air, and therefore degrades more rapidly. A dirty coil reduces the cooling capacity of the air blowing across it. For example, if the dirty coil results in an increase in the condensing temperature from 95°F to 105°F, then cooling capacity will decrease by 7% and power draw will increase by 10%.

The best tool for cleaning the coils is a power washer that feeds cleaning solution into a high-pressure water flow. Some companies specialize in performing this type of cleaning at a competitive price. They typically use tank trucks and custom self-contained equipment. Spray-on cleaning solutions that are intended to be used with a brush and a hose may not do a good enough job of cleaning the coils, even though they may brighten the outer surface.

Before-and-after measurements of the temperature difference across the coil will verify the effectiveness of the cleaning. These measurements should be included in a report to the store owner or supervisor. Power washing, if done improperly—for example using the wrong spray angle or excessive pressure—can damage coils by bending the fins, or even breaking them off if the coil is old.

Burners. Over time, burners can become fouled due to buildup from minerals, corrosion or soot, reducing the efficiency of the combustion process. Burners should be checked regularly for cleanliness and proper flame control. There are several indicators that a burner needs cleaning. Burners may be overfiring, indicated by a large flame blowing past the thermocouple that measures the temperature of the flames. An under-fired burner will have a small flame that doesn't engulf the thermocouple. A flame with a yellow tip suggests a lack of primary air. Yellow or orange streaks indicate that dust or other particles are present and this will lead to soot buildup. Perform regular maintenance to keep burners clean by removing burners and brushing and vacuuming thoroughly. Check to ensure that all ports are free of debris before placing them back in their original position. This will help the heating system achieve peak combustion efficiencies.

E.6.3 Clean and/or replace air, water, and lubricant filters

Filters help maintain IAQ and protect the downstream components of an air-handling system (the evaporator coil and fan) from accumulating dirt. Filter-changing intervals are typically determined by calendar scheduling or visual inspection, but can also be based on the measured pressure drop across the filter. Scheduled intervals are usually between one and six months, depending on the local air quality, both indoors and out. More frequent changes may be needed during the economizer season, because outdoor air is usually dirtier than indoor air.

Measuring pressure drop is the most reliable way to determine if filters need cleaning, but requires some effort because most rooftop units do not have built-in pressure taps. Taps can be made by drilling into the cabinet wall and installing quarter-inch tubing with removable caps. A technician can then use a hand-held pressure meter or manometer to check filter status. To get accurate readings, cabinet access panels must be shut tightly, with all screws replaced. In facilities with predictable and regular filter loading, pressure measurements can be used to establish the proper filter-change interval; thereafter, filter changes can simply be scheduled.

E.6.4 Verify correct operation of outside air economizer

Economizers provide "free" cooling by drawing in cool outside air to offset mechanical cooling when outside temperatures are sufficiently low (Figure E–2). When economizers operate as designed they can save considerable amounts of energy. Simulations for eight cities across the United States show that standard economizers can cut HVAC energy use by 1%–5%; and high performance units can save 8%–20%. Savings are greatest in milder climates (Hart 2011).

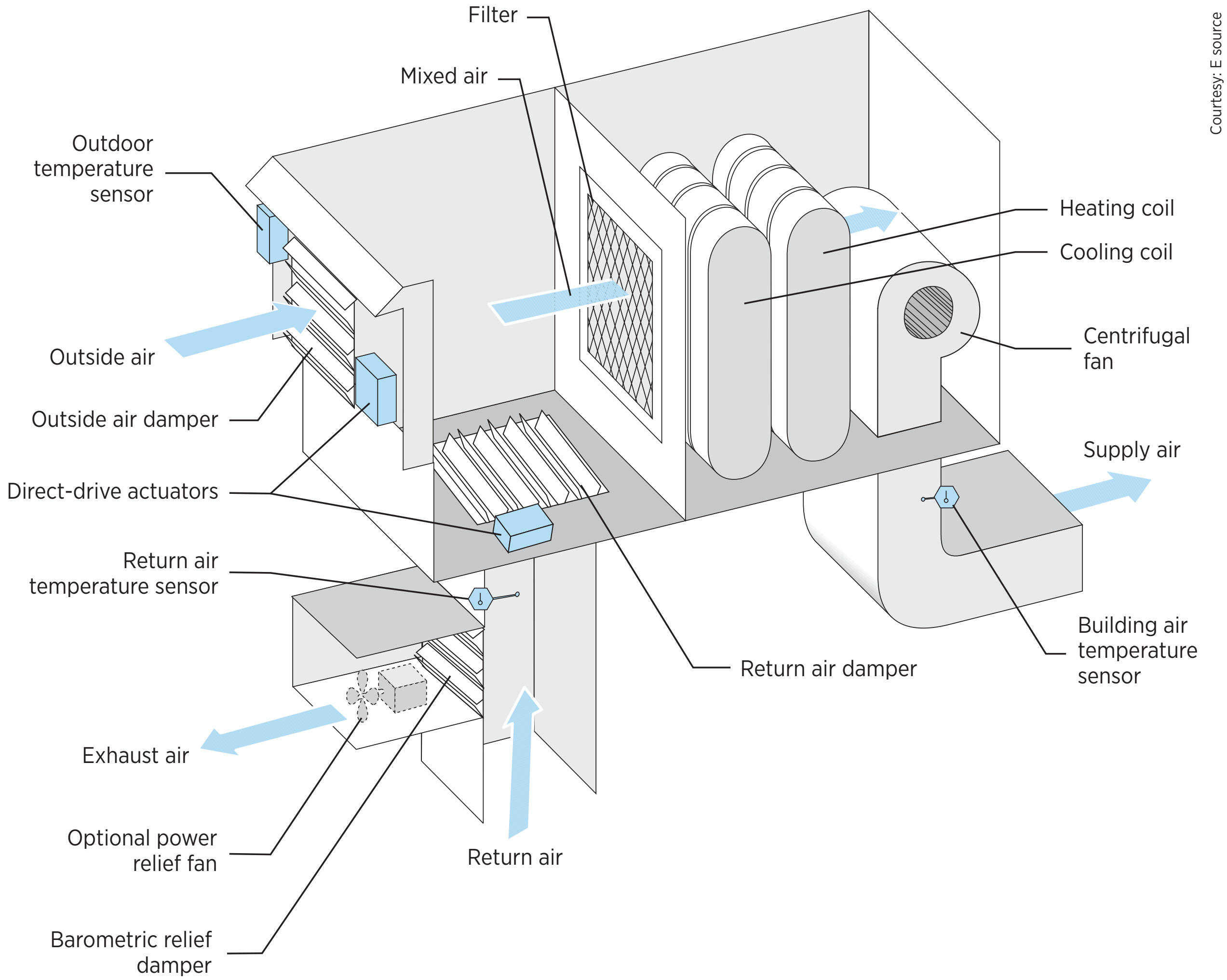

Figure E–2 Economizers include a number of components that must be properly maintained

However, economizers often don't operate as designed. Between 2001 and 2004, the New Buildings Institute compiled the results of several field studies conducted in the western United States. Inspectors found that out of 503 economizers on rooftop HVAC units, 64% had failed or required adjustment (Cowan 2004). Common problems included corrosion-frozen dampers, broken linkages between the actuator and damper, malfunctioning OA temperature sensors, and improperly set controls.

Because economizers are exposed to unfiltered OA, the pivot points and actuators can easily get dirty and bind, resulting in serious energy waste. Economizers stuck in the open position risk overloading the cooling coil with warm OA while economizers stuck in the closed position eliminate the free cooling potential. One study estimated that economizer malfunctions waste 20%–30% of all HVAC energy consumed (Roth et al. 2002). One simulation showed that in hot humid locations, if an economizer damper is stuck in the open position, it can increase energy use by as much as 50% (E Source 2009).

To ensure that economizers provide energy savings, implement an annual maintenance program that includes functional testing, which can identify failed actuators, linkages, and stuck dampers. PECI provides a free checklist for economizers: *Functional Performance Test, Air-Side Economizer*; and PG&E offers a *General Commissioning Procedure for Economizers*; Portable dataloggers can also help identify problem areas, as described in this *application note* from PG&E's Pacific Energy Center. BASs can also be used to monitor economizer performance if they are equipped with the right sensors and diagnostic software.

Regular maintenance should also include cleaning, lubricating and inspecting dampers on a regular basis—up to three or four times per year. Cleaning can be performed with a power washer or with soapy water and a brush. Once the dampers are cleaned, they should be run through their full range of motion. Lastly, the economizer set point should be checked and damper response confirmed.

Economizer maintenance costs are hard to pin down because service contracts usually cover the air-conditioning system rather than specific components. A survey of HVAC contractors across the United States found the cost of a service contract for a 10-ton unit to be in the $1,000 to $1,200 range, but coverage varied: some only provide visual inspections of economizers, while others perform functional testing (E Source 2009).

E.6.5 Ensure correct refrigerant charge in cooling systems and heat pumps, and repair any refrigerant leaks

Refrigerant system charge should be checked, and the system inspected for leaks, at least annually, but seasonal check-ups may be more valuable if this is a new task for maintenance or the system is frequently leaking. Inspecting charge levels can be completed as part of a TAB analysis or as a stand-alone maintenance task for the cooling system. An improperly charged refrigerant system not only reduces system efficiency by as much as 50% (Criscione 2004), but can also damage cooling equipment. An under-charged system leads to increased loads on the compressor, causing it to run continuously; low suction and head pressures; and an inability to maintain temperature set points within designated ranges. An over-charged system results in high head pressure, increasing the compressor load; and may also flood the condenser, reducing its capacity. In addition, if the cooling system has any components susceptible to leaking, an over-charged system will increase the risk of refrigerant leaks.

E.6.6 Increase thermostat set-back/set-up when building is unoccupied

During closed hours at night and on holidays, turn temperature settings down in heating seasons and up in cooling seasons. Set temperatures according to climate, season, and length of time the space is unoccupied. For example, during the heating season, for long breaks over the weekend or a holiday, the temperature can be set back to 55°F, while 60°–63°F may be more appropriate for a shorter break (ASE 2009). The optimal temperature setbacks will depend on the specific systems and features of the building and climate. In general, energy savings from thermostat setbacks are greater for facilities in milder climates compared to those in more severe climates.

Changing temperature settings for different times or situations is easiest to accomplish with an EMS or BAS. If those systems aren't in use, programmable thermostats can accomplish the same thing. With either approach, be sure to allow enough time in the morning to bring the facility back to a comfortable temperature before customers arrive. Training of store staff is necessary to ensure proper programming and maintenance.

You can also save energy by making sure that HVAC settings in warehouses, stockrooms, offices, and other special use rooms are adjusted to meet the needs of the space.

E.6.7 Re-optimize supply air temperature reset based on current building loads and usage patterns

If the right controls are in place, the SAT can be reset to reduce energy. In typical constant volume (CV) HVAC systems, the SAT for the building is set at a constant set point, around 53°–55°F, to satisfy cooling demands on the hottest day of the year, and is designed to provide cooling to the zone with the highest demand. To maintain comfortable conditions in zones with lower cooling loads, air will be reheated as it enters the zone. To minimize this simultaneous cooling and heating, the SAT can be reset. In this approach, cooled water flow is reduced to create warmer supply air (reset) in response to a decrease in cooling demand. This reset is controlled by measuring OA temperatures (OA reset) or by measuring the warmest area (warmest zone reset). The warmest zone reset approach is more accurate because control is based on measured indoor air temperatures. However, OA reset uses much simpler controls.

If the existing system is a VAV system, the optimal SAT, which depends on local conditions, minimizes the combined energy consumption for fan, cooling, and heating. For example, low SAT can be a better choice in warm and humid climates where there are fewer potential economizer hours and dehumidification is important. Based on simulations of VAVs in various climates, the *Advanced Variable Air Volume System Design Guide* from the California Energy Commission provides general guidelines for optimizing systems (CEC 2005a).

E.6.8 Verify adequate deadband between heating and cooling

HVAC systems switch between heating and cooling modes depending on the room temperature. Typically, there is a deadband, or temperature range in which no heating or cooling is provided. The narrower the deadband, the more time and energy the HVAC system has to spend meeting those conditions. In addition, if the deadband is too narrow, simultaneous heating and cooling can occur as the HVAC system bounces back and forth between heating and cooling set points. When these systems compete against each other, they waste large amounts of energy and unnecessarily cycle systems on and off. Widening the deadband by increasing cooling setpoints and lowering heating setpoints will save energy and reduce runtime and therefore maintenance costs on fans, pumps, furnaces, and compressors. One study found that increasing the deadband by 5°F saved over 400,000 kWh and 500 Therms annually (PECI 2007a).

However, there is a limit to how wide a deadband can be, because the wider the deadband, the more likely occupant comfort will deteriorate. In particular, buildings with wide deadbands in humid climates can experience large variations in relative humidity. As a rule of thumb, deadbands should be between 5°F and 15°F during occupied periods (Price and Rosenow 2010), but to determine the optimum setting, widen the deadband gradually and determine if occupants are still comfortable. ASHRAE Standard 55-2004, "Thermal Environmental Conditions for Human Occupancy," states that buildings' temperature setpoints can be adjusted according to the way occupants dress (ASHRAE 2004). This allows cooling set points to be raised during the cooling season because building occupants dress lighter. Similarly, heating setpoints can be lowered during the heating season as occupants dress more warmly. Adjusting these set points should be conducted over several weeks so that occupants won't notice significant changes.

E.6.9 Move improperly located thermostats to prevent over- or under-cooling/heating

Thermostats should be placed on an interior wall, away from any direct sunlight from skylights or windows. They should also be placed away from areas with high airflows—avoid proximity to windows and doors or other areas known to be drafty. Avoid installing a thermostat directly beneath a duct outlet as this will cause the system to continuously turn on and off.

E.6.10 Test, adjust, and balance air handlers and flow modulation devices to ensure that conditioned air volumes meet load requirements

If your retro-commissioning effort finds inadequate air distribution, fluctuating indoor temperatures, and over-ventilation of vacant rooms, then it is time for TAB. TAB will bring the HVAC system back into balance and maximize occupant comfort while minimizing energy waste.

The TAB process involves testing the functionality of existing equipment and making improvements and repairs as needed, adjusting system parameters, and balancing all system parameters to efficiently match building loads and ordinances. Typical system parameters like air flow rates (supply, return, exhaust, and OA) and terminal unit set points would be investigated during a TAB analysis. Other equipment problems, such as air handler leaks through faulty seals or panels, may also be revealed through TAB.

If customers or employees are frequently complaining about indoor comfort issues, TAB may be needed. TAB analysis should also be conducted as part of recommissioning efforts and after any major renovations. While savings through TAB are hard to generalize because they depend heavily on existing building conditions, improper operation of the air distribution and ventilation systems will eventually lead to customer discomfort and/or wasted energy.

E.6.11 Update and maintain a systems manual with O&M requirements

In order to maintain savings from building commissioning activities, an O&M program must be in place. This will not only help retro-commissioning benefits last longer, but will also help critical building systems avoid unexpected shutdowns due to equipment failure or malfunction.

A key element of an O&M program is a system manual that covers O&M requirements for all equipment within the building. The manual should include scheduled maintenance activities, ideal set points and schedules, logs of recently completed work, and more. Manuals should be updated whenever equipment is replaced or upgraded. For help or other ideas on putting these manuals together, PECI offers an *O&M best practice guide* for starting an O&M program, and FEMP provides another *O&M best practice guide* that includes specific task items for major building equipment.

E.7 HVAC: Ventilation

E.7.1 Suspend ventilation during unoccupied periods

Most buildings base their ventilation rates on ASHRAE Standard 62.1, which specifies the minimum amount of OA that needs to be brought into the building, depending on its type and use (ASHRAE 2010). This approach usually leads to a fixed ventilation rate based on assumed occupancy. However, grocery store occupancy varies throughout the open hours and stores are usually closed during the night. If ventilation systems are still operating at full capacity during unoccupied periods, there are large savings available. Suspending ventilation during unoccupied periods not only saves fan energy and heating and cooling loads, but also reduces wear and tear on ventilation equipment, extending system life and lowering maintenance costs. In addition, in humid climates, unnecessary ventilation during unoccupied periods can lead to elevated relative humidity levels. This results in occupant discomfort and increased demand on the HVAC system to bring humidity down to acceptable levels. One field study by the California Energy Commission (CEC) found that 30% of observed buildings operated ventilation fans during unoccupied periods (CEC 2005b).

E.7.2 Test and adjust ventilation flow rates as needed to meet ASHRAE 62.1 requirements

Grocery store ventilation rates should meet ASHRAE Standard 62.1, which sets different requirements for different parts of the store. These rates are critical to maintaining healthy IAQ. However energy can be saved by testing and adjusting ventilation rates not to exceed the requirements. In addition, because occupancy rates change frequently in the course of the day, a DCV system can lead to significant savings.

E.8 Additional Measures for Consideration

Several of the most important and frequently-occurring EBCx measures have been discussed in the preceding paragraphs. Many additional low-cost measures can be worth exploring, depending on the state of the existing systems. A number of these measures are listed in Table E–2, and further possibilities can be found in the reference documents listed in Section 3.4.

Table E–2 Additional EBCx Measures That Should Be Considered for Grocery Stores

System	EEM Description
Lighting	Clean lamps, fixtures, and diffusers
	Activate any disabled controls if the reason for disabling can be addressed or if there no reason for disabling is evident
	Improve sensor locations/move line-of-sight obstacles
Plug and process loads	Calibrate cooking equipment temperature settings, repair broken knobs, and ensure pilot light isn't overlit
	Turn off refrigerator door heaters
Refrigeration	Insulate refrigeration lines and ensure adequate shading of remote condensers
	Install floating head and suction pressure controls, optimized for night curtain use, split condenser and fan control operation
	Auto closers on walk ins and reach ins
	Load cold items into refrigerated cases quickly after received
Building enclosure	Repair broken windows
Service water heating	Repair pipe and tank insulation
HVAC	Calibrate temperature and humidity sensors for HVAC controls
	Align/tighten belts and pulleys
	Post the correct operating parameters near each piece of equipment
	Turn off unneeded heating/cooling equipment during off-seasons
	Calibrate time clocks
	Optimize equipment start/stop procedures
	Seal leaky ducts
	Replace or repair leaky and broken dampers
	Verify that exhaust air is released outside the building, not the attic

Appendix F

Detailed Retrofit Measure Descriptions

F.1 Lighting

Lighting is the second largest electricity end use in a grocery store, representing an average of 18% of electricity consumed. Using a variety of technologies mixed with daylighting measures can create an aesthetically pleasing environment, enhance product appearance, and as a result, bring in new business and increase sales. There are a variety of lighting retrofits available to grocery stores based on the specific lighting need.

F.1.1 Replace T-12 fluorescent lamps and magnetic ballasts with high-efficiency T-8 lamps and instant-start electronic ballasts

T-12 fluorescent lamps with magnetic ballasts are rapidly becoming the dinosaurs of the fluorescent lighting world: federal legislation has eliminated most magnetic ballasts for T-12 lamps and recent DOE regulations will eliminate the most common T-12 lamps as of July 2012. If you have not already upgraded to T-8 lamps with electronic ballasts, or if you upgraded to T-8s, but not the most efficient models, than you can get big savings from a lighting retrofit (Table F–1). The newest, high performance T-8 lamps and NEMA Premium ballasts not only boost efficiency but also offer improved color quality and longer lamp life. All upgrades to more efficient lighting also reduce the cooling loads on store air conditioning equipment.

Table F–1 Efficacy of High-Performance T-8 Systems Compared With the Most Popular Standard Lamps and Ballasts

Technology	Light Output (mean lumens/W)	Percent Efficacy Improvement	
		Over Original T-12	Over Generic T-8
Magnetic T-12, with original magnetic ballast and 40-W holophosphor lamps	54	–	–
Magnetic T-12, with energy-saving ballast and 34-W holophosphor lamps	54	None	–
Generic T-8, with instant-start ballast and commodity 32-W 700 series CRI lamps	75	39%	–
High-performance T-8, with programmed-start ballast and 32-W 800+ series CRI lamps	92	70%	23%
High-performance T-8, with instant-start ballast and 32-W 800+ series CRI lamps	98	81%	31%

F.1.2 Replace incandescent ambient lighting with CFL and accent/display lighting with ceramic metal halide

CFLs are a good choice for replacing incandescent lamps for ambient lighting. They cost more initially than incandescent lamps but pay for themselves quickly through energy and maintenance savings. The longer the annual operating hours, the more attractive the economics of CFLs become because more incandescent relamping costs are being avoided each year.

CFLs come in two general forms—self-ballasted and pin-base. Self-ballasted CFLs—also known as screw-base, screw-in, or integrally ballasted CFLs—can replace incandescent lamps without modifications to the existing fixtures. They combine a lamp, ballast, and base in a single sealed assembly that is discarded when the lamp or ballast burns out.

Pin-base CFLs, the type most commonly employed in commercial buildings, are used with separate ballasts. They are available in lower power versions, which can replace incandescent lamps, and in higher power versions, which can replace linear fluorescent lamps or HID lamps. Pin-base systems feature a ballast and pin-base fluorescent lamp socket that is wired into a fixture by the fixture manufacturer or as part of a retrofit kit. Because they are hardwired, dedicated systems, they eliminate the possibility that a user will return to using an inefficient incandescent bulb.

When using CFLs, remember these key points:

- **Go for a 3:1 ratio.** Lamp manufacturers often publish a 4:1 ratio for replacing incandescent bulbs with CFLs (that is, a 25-W CFL can replace a 100-W incandescent lamp). A 3:1 ratio is more appropriate (a 25-W CFL can replace a 75-W incandescent lamp) because, in practice, CFL output is lower than the nominal rating due to lumen degradation and the effects of temperature and position on lamp output.
- **Limit the number of CFL types.** CFLs are available in a wide variety of sizes and shapes—it is useful to standardize on just a few types to reduce stocking requirements and confusion at relamping time.
- **Use dedicated fixtures.** To prevent the replacement of CFLs with incandescent bulbs when it is time to relamp, use dedicated fixtures that will accept only pin-based CFLs.
- **Choose CFLs that have earned the ENERGY STAR rating.** This rating from the EPA ensures reliability as well as efficiency in self-ballasted CFLs (visit ENERGY STAR, *Compact Fluorescent Lightbulbs*, for more information).

The light output from a CFL may be too diffuse for accent and display lighting, but lower wattage ceramic metal halide (CMH) lamps are available that provide directed light output with three times the efficiency of the halogen lamps typically used, provide longer lamp life, and good color quality. However CMH lamps cannot be dimmed as deeply as halogens. CMH lamps are available in wattages ranging from 20 to 400; last 12,000 to 15,000 hours in the smaller sizes used for display lighting, and come in most common configurations including PAR20, PAR30, and PAR38.

Rapid improvements in efficiency and reductions in cost are also making LEDs a viable option for accent and display lighting. One of the main challenges with LED lighting is distinguishing the good products that are available from the numerous bad products that are in the marketplace. See DOE's *Solid State Lighting* website for the latest on LED technology.

F.1.3 Replace refrigerated display case lighting with LEDs

LEDs perform very well at the cold temperatures found in refrigerated cases, unlike the conventional choice, fluorescent lamps, for which output decreases appreciably as temperatures drop. LED light output can also be narrowly directed, so less light is wasted. These two properties mean that fewer lumens will be necessary in the design of the display case lighting. LEDs are also easier to control than other light sources, and, although frequent on-off cycling shortens the life of a fluorescent lamp, it has little impact on an LED. Therefore, LEDs can be used with occupancy sensors that turn off the lights when no one is near. This feature can also lengthen the life of LEDs—the more time the LEDs spend turned off, the longer the lamps will last. A typical refrigerated display case with LED lighting is shown in Figure F–1.

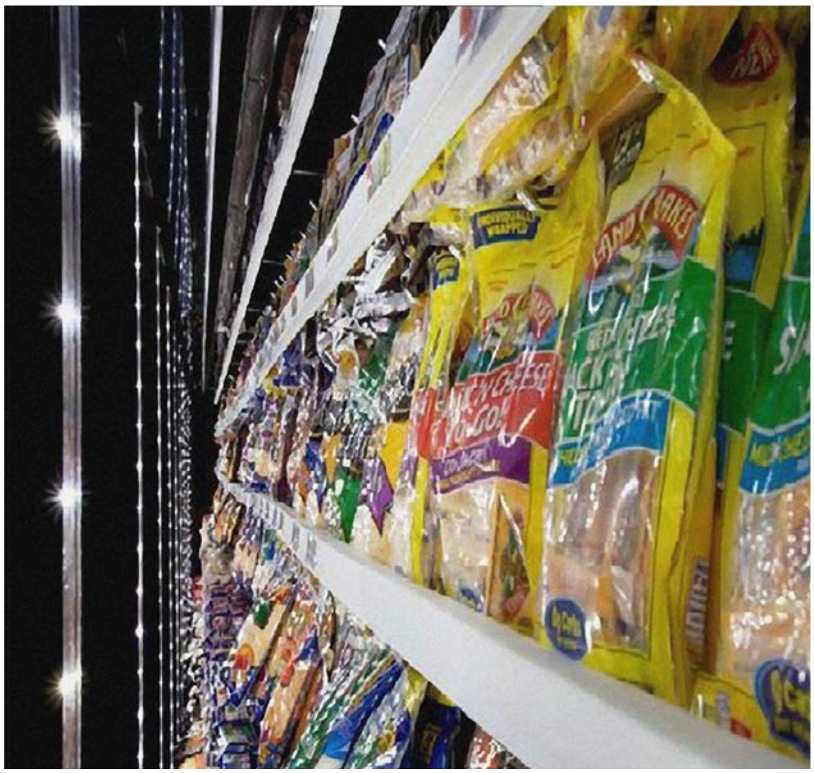

Photo by Patrick Corkery, NREL/PIX 15789

Figure F–1 LED lighting in a refrigerated display case at a Walmart store

The use of LEDs reduces case compressor loads for a number of reasons. First, less waste heat is generated because designers can use lower-wattage lighting with LEDs than they can with fluorescents. Second, the heat sink for an LED can be placed so that at least some of the waste heat is dissipated outside the case; with fluorescent lighting, most of the waste heat must be offset with additional cooling inside the case. And third, if LEDs are used with occupancy sensors, they will be on less than full-time, meaning that they will contribute less to the cooling load.

PG&E conducted field testing of the technology and found energy savings of more than 40% in each refrigerated case. About two thirds of the savings was due to lighting load reduction, and about one third came from reductions in the refrigeration load. Additional savings came from reduced maintenance costs, for an estimated payback period of 4.5 years (PG&E 2008). Since those tests were conducted, LED performance has improved and even greater savings are possible.

F.1.4 Install wireless motion sensors for lighting in rooms that are used intermittently (break rooms, storage areas), and for lighting in refrigerated display cases

Occupancy sensors for lighting control use infrared or acoustic technology, or a combination of the two. Most systems incorporate a delay time before switching lights off. This delay time is often user-selectable, but a typical default value is 15 minutes. This means that the sensor must detect no motion for the entire delay time before the lights are switched. Most systems switch lights off at the end of the delay time, but more sophisticated systems with dimming technology reduce lighting slowly to a minimum level (or zero) over several minutes, to minimize the potential disruption in adjacent spaces. If lights are off and an occupant re-enters a space, most current systems switch lights back on when motion is detected. However, vacancy sensors are gaining in popularity due to their potential for increased energy savings. They are designed to switch lights off automatically with no occupancy, and require the occupant to switch lights on when they re-enter.

Sensor placement is also crucial to success. Wall-mounted sensors are suitable in smaller rooms—offices, bathrooms, and equipment rooms that are only intermittently occupied. In larger spaces or wherever the lighting load is higher, it is better to mount the sensor in the ceiling. Some units can be mounted in the corner or on the wall near the ceiling. Installation of conventional occupancy sensors can be time-consuming, but wireless models are now available that ease the task. For more details, see Chapter 6 of the EPA *Building Upgrade Manual* (EPA 2008)

The level of savings that can be achieved varies with the type of space and local circumstances. Table F–2 shows values of savings for spaces typically found in grocery stores (Maniccia 2010).

Table F–2 Savings From the Use of Occupancy Sensors (Maniccia 2010)

Type of room	Typical lighting energy (%) savings
Break rooms	18 to 29
Copy rooms	50 to 70
Hallways	30 to 80
Private offices	25 to 50
Restrooms	30 to 75
Storage rooms	45 to 80

Credit: E Source

The savings found when motion sensors are used with display case lighting will also vary with local conditions—how long the store hours are, the amount of traffic in the case aisles, and how the lights are controlled. Some stores turn the lights off if the aisles are vacant, others dim the lights. In an installation at an Albertsons Grocery in Eugene, Oregon, occupancy sensors dimmed the lights for about 40% of the time (DOE 2009b).

F.1.5 Install timer controls for non-essential lighting when building is unoccupied

For areas that are occupied on a set schedule, clock switches can be used to control lights by turning them on and off at prearranged times. The switches are typically placed in electric closets that house lighting power panels. These devices cost relatively little to install and can control large loads with a single set of contactors. Equipment may consist of mechanical devices—motors, springs, and relays—or sophisticated electronic systems that handle several schedules simultaneously. Mechanical switches may require correction for daylight savings time or after a power failure unless battery backup is available, but battery backup can triple the device's price. Electronic devices routinely include battery backup and can be easily programmed to adjust for shifts to and from daylight saving time or for holiday schedules.

F.1.6 Install photosensors and dimming ballasts to dim lights when daylighting is sufficient

If there is sufficient daylight in a store, photosensors and dimming ballasts can be installed to adjust the electric lighting in response to the available daylight (see Figure F–2). Benefits include reduced electric energy use, a possible reduction in peak demand charges, the ability to participate in utility demand response programs, reduced HVAC loads, and a more desirable indoor environment. Studies have shown that shoppers prefer a daylit ambience (HMG 2003).

Photo by Jennifer Scheib, NREL/PIX 18608

Figure F–2 Ambient electric lighting is dimmed at this Whole Foods Market

When implementing a daylighting system, it is crucial to commission the system. Many daylighting systems fail to deliver the expected benefit because they are not commissioned. Commissioning consists of adjusting photosensors and ensuring proper sensor placement so that the electric lighting system responds properly to the presence of daylight. Properly planning and implementing a lighting control system will reduce the chances of overdimming, underdimming, and rapid cycling—problems that frequently occur in daylighting systems. These problems can often lead to users overriding the control system and eliminating any savings.

Also, rooms on the south side of buildings may experience excessive heat gains in sunny weather, if the blinds or shades are opened and the lights dimmed. During the winter, some rooms may experience excessive glare from direct sunlight, which can be mitigated with retrofitted light shelves and/or window films.

For more information on daylighting and a list of resources, see the *EPA Building Upgrade Manual,* Chapter 6.

F.1.7 Increase the availability of daylight through the addition of skylights, tubular daylighting devices, or hybrid solar lighting that collects and distributes sunlight via optical fibers to the building interior

Making use of daylight in a grocery store environment can reduce energy use and improve the shopping environment, as noted above. Local utilities may also provide incentives for daylighting projects because the use of daylight helps to reduce peak demands, which often coincide with periods of peak daylight. In a retrofit project, available daylight can be increased through the use of horizontal skylights, tubular skylights, and fiber optic light transport systems. All these measures need to be combined with controls that modulate electric lighting in response to the amount of daylight available.

Skylights are a common means of introducing daylight into an existing space. However horizontal skylights are particularly susceptible to heat loss and direct solar gain, as well as glare, so they should be chosen with care for daylighting applications. The *Energy Design Resources* program, sponsored by the California Public Utilities Commission, offers a number of skylight references including design guidelines and software.

Tubular daylighting devices (TDDs) (sometimes called tubular skylights) eliminate the problems that sometimes plague conventional skylights: uncontrolled light and excess glare. Tubular devices feature the following elements:

- A clear plastic dome that sits on the roof and lets in sunlight,
- A reflective tube that carries light into the interior, and
- A light diffuser—which looks like a ceiling light fixture—that sits on the ceiling and distributes light around the room.

Most TDDs also feature a reflective sun scoop in the rooftop assembly that directs sunlight into the reflective tube. Some tubular skylight products come with integrated electric lights, and baffles to regulate the amount of incoming sunlight. Tubular skylights are most often used on the top floor, just below the roof, although can they be used to bring light down to lower floors.

To get sunlight deeper into a building, systems that track and focus the sun into fiber optic cables are becoming available (Krepchin, 2006). The fiber optic cables bring sunlight into the building interior and emit it through a fixture that looks like a conventional lighting fixture. Compared to more traditional skylights, these systems enable smaller roof penetrations, more flexibility in placing the systems, and less heat loss or gain through the building envelope. However, they can be costly and are only effective with direct sunlight as opposed to the diffuse light available on a cloudy day. They are also more complex and costly than standard skylights.

F.2 Refrigeration and Cooking

Refrigeration is by far the largest end-use category for supermarkets and grocery stores, accounting for, on average, 60% of a store's electricity consumption. It also represents the most effective area for upgrades for stores in all climates. Energy used by cooking appliances in the deli and bakery areas is also a substantial load in grocery stores. Significant energy savings can be realized through retrofit and replacement of older equipment.

F.2.1 Install high-efficiency ECM evaporator fan motors

Most refrigeration evaporator systems come equipped with split capacitor or shaded-pole induction motors for the evaporator fans. While these small fan motors do not use much energy individually, collectively they can use a large amount. Replacing these standard fan motors with high-efficiency ECMs can reduce the power consumed by fans by about one third (Sator, 2008).

ECMs are brushless permanent magnet motors that achieve high levels of efficiency by using an electronic AC inverter to drive an inherently efficient DC motor. NREL worked with Whole Foods to replace split-capacitor fan motors with ECMs in equipment going into a new Whole Foods Market in Raleigh, North Carolina. The measure was one of several identified for Whole Foods by NREL as part of a project for DOE's Commercial Buildings Program. Although they could not replace all of the fan motors because some specialized manufacturers did not offer fans with ECMs, the total case fan power draw was still reduced by 36%, from 15.0 kW to 9.6 kW (Deru et al. 2011a).

F.2.2 Install night curtains to reduce load on open refrigerated cases

For stores that are not open 24 hours per day, installing night curtains, sometimes called night covers, on open refrigerated cases can lower the refrigeration load on the case, reducing the power consumption of the compressor. Refrigerated cases are designed to drop a curtain of cold air down the face of the case, keeping items within the case at required temperatures while allowing customers to browse freely and reach in for whatever they choose. While convenient to customers, the design sets up an endless fight against the infiltration of warm air. Night curtains can be drawn down across the open face of refrigerated cases when stores are closed, reducing the amount of warm air entering the cases.

A report by SCE studied the effects of night curtains in a store that closed for six hours per day. Once the night curtains were installed, the load on the refrigerated cases fell 12% while the store was closed, and power consumption dropped 9%. The curtains kept refrigerated items at lower temperatures up to 15 hours after the curtains were removed. Furthermore, SCE observed the savings from using the curtains during a holiday where the store was closed for 24 hours. In that scenario, the refrigeration load was reduced by 41% and compressor power was reduced by 36% (SCE 1997).

F.2.3 Install doors on open vertical refrigerated cases

Grocery stores and supermarkets can take the night curtain concept a step further by installing doors on open vertical refrigerated cases (see Figure F–3). These doors are similar to the doors used on low temperature cases for frozen foods. The energy savings from this measure are vast—one study found that installing doors on medium-temperature refrigerated cases reduced refrigeration load by 65%, which reduced compressor power demand by 87%—all without hurting sales (Fricke and Becker 2010). The large drop in refrigeration demand meant that a 15% smaller compressor rack could have been used at the store in question. Modeling by NREL for the Whole Foods project showed that adding doors to 132 linear feet of medium-temperature vertical cases would reduce the necessary refrigeration capacity by 10 tons (34 kW), which was approximately one quarter of the entire medium-temperature cooling load in the store (Deru et al. 2011b).

Photo by Jennifer Scheib, NREL/PIX 18606

Figure F–3 Doors installed on medium-temperature refrigerated cases at a Whole Foods Market

Refrigerated case doors also keep cold air from spilling into the aisles, which would otherwise create uncomfortable cold spots for customers and cause the HVAC system to work harder to meet system set points. As this cold air leaks out, it forces warm air up to the ceiling while the much more uncomfortable cold air occupies the floor space. Building staff will typically use higher than normal ventilation rates to mix the cold and warm air, consuming high amounts of energy. The doors reduce this excess load on the HVAC system while also improving shoppers' comfort. An additional benefit is eliminating the temperature variance seen in open cases, improving product quality.

F.2.4 Install controls to disable anti-sweat heaters when dew point is low

Freezer cases and refrigerated cases with doors typically feature ASHs that prevent glass from fogging up with condensed moisture by warming up the interior of the glass doors. Condensation can form on the inside surfaces of case doors when store temperatures and humidity are high, impeding shoppers' view of the products inside the case. However, when humidity is reduced and the dew point is low, condensation is not a concern and there is no need turn on the heaters. Controls for ASHs exist that can measure the ambient humidity and temperature in the store, calculate the dew point and turn the heaters on or off as needed. Installing these ASH controls can provide significant savings and short payback periods.

There are at least two different utility programs that used deemed (estimated) savings to justify incentives for ASH controls. Both programs used the findings of a Select Energy Services (SES) report that studied several EEMs for refrigeration systems. The report asserts that when controls are installed, ASH in freezer cases will be turned off 46% of the time and heaters in medium-temperature cases will be turned off 74% of the time (SES 2004).

The greatest savings potential for this measure occurs in hot humid climates. The same SES report shows a positive correlation between wet-bulb temperature and heater operation.

F.2.5 Install variable speed drives on condenser fans for the refrigeration system

Refrigeration systems are designed to handle the worst conditions: frequently opened cases during times of high temperatures and high humidity. However, these conditions are rare—most days the refrigeration system does not need to operate at full capacity. A VSD will allow fans to operate at the appropriate speed, which produces a significant reduction in energy consumed—energy use is roughly proportional to the cube of the fan speed. Operating at variable speeds will also reduce the frequency of on/off cycling that accompanies full speed operation under partial load, an effect that will reduce the wear and tear on the system.

Predicting the savings from a particular VSD application is difficult, but payback periods for installations on condenser fans are typically two years or less (Robinson and Scepaniak 2007).

F.2.6 Install evaporative condensers for refrigeration systems

Evaporative condensers spray water across the condenser coils, absorbing the condenser heat as it evaporates. Because evaporating water can remove more condenser heat than a stream of ambient air, evaporative condensers provide lower condenser temperatures and pressures—and the compressors can therefore run at lower power. The savings from evaporative cooling decrease in humid climates where there is less potential for evaporation; savings also decrease with smaller units, as the parasitic energy consumption of the water pump increases relative to compressor energy savings.

Water costs and mineral buildup on condenser coils are maintenance concerns with indirect evaporative cooling systems. The life cycle cost of evaporative cooling equipment must be carefully evaluated relative to the predicted energy savings. Evaporative cooling systems can save energy when compared to a cooling system that is completely refrigerant-based. Walmart and NREL participated in one study where several new Walmart stores were built with experimental systems designed to reduce energy use. A store in Aurora, Colorado, featured a refrigeration system with an evaporative condenser. NREL used another local Walmart store with an equivalently-sized refrigeration system using a standard condenser to provide an energy-use baseline. NREL found that the monthly compressor energy use with the new evaporative condenser was about 4,000 kWh less than the standard compressor during the winter and used around 16,000 kWh less during the summer (Deru et al. 2010).

F.2.7 Install strip curtains and weather seal walk-in freezer doors

One of the biggest threats to walk-in freezer performance is air infiltration, which occurs through an inadequately sealed door, and/or when the door is opened. Installing strip curtains and weather-sealing the doorway is a proven way to keep warm air out. Strip curtains are typically large, clear sheets of plastic that cover the walk-in freezer doorway. Vertical slits allow people and equipment to easily pass through. One study performed by the Davis Energy Group (DEG) modeled the potential energy savings for an 80-ft^2 walk-in freezer that used 15,600 kWh/yr. The model showed that installing strip curtains on a walk-in freezer of this size would save over 5,000 kWh annually (DEG 2004).

The process of weather-sealing freezer doors begins with an inspection of door gaskets to see if the door gasket is making contact all the way around the opening. Gaskets in disrepair should be replaced immediately and gasket inspection should be a task on any regularly scheduled maintenance plan. Remember that the door gaskets are used for more than keeping the hot air out—they're also in place to keep the cold air in. Any other openings around the doorway or the freezer itself should be caulked and sealed, particularly around any pipework that may be protruding through the freezer shell.

F.2.8 Install compressor unloaders for capacity control, with electronic controls

Installing compressor unloaders helps better match compressor capacity to actual load. A refrigeration system's capacity is designed for the worst conditions (hot and humid days) plus a safety factor. Otherwise, the system runs at part-load a majority of the time. Compressor unloaders reduce pumping capacity during periods of low-demand by holding valves open, reducing the number of active cylinder heads pumping refrigerant. This approach is similar to that used in a car engine that can operate with either four cylinders or eight, depending on the demand on the engine at any given time. When the load on the system starts to increase, pressure forces the unloader valves to close, allowing the cylinder to start pumping normally again. Matching compressor capacity to refrigeration system demand saves energy by decreasing the power required to run the compressor and increases product integrity by providing a more constant and accurate temperature inside the case.

F.2.9 Install smart defrost controllers in walk-in freezers and low-temperature cases

Walk-in freezers and low-temperature cases use defrost cycles to control and eliminate ice buildup on the evaporator coils. Typically, these defrost cycles operate on a time-based schedule, whether defrosting is actually needed or not. Smart defrost controllers use an adaptive control algorithm to detect when the freezer needs a defrost cycle, thus saving energy by eliminating the unnecessary defrost cycles. In addition, fewer defrost cycles creates a more constant temperature profile, benefiting the quality of the perishable items within the freezer or refrigerated case.

These controls are labeled smart because they can create a baseline for performance based on data collected when the controls are first installed. Using the baseline, the controls can then determine when the defrost cycles are needed and when they're not. In one field study, a manufacturer of these controls found that smart defrost controls reduced the number of defrost cycles by 30% (Criscione 2006). Another utility program with an incentivized measure for installing smart defrost controls based its incentive on an estimated 35% reduction in defrost cycles (Massachusetts Electric and Gas Energy 2010).

F.2.10 Install walk-in freezer alarms and automatic door closers to reduce time when doors are left open.

If a walk-in freezer door is left open, warmer air will flow in and not only raise the cooling load, but also have a negative impact on the quality of the produce being stored. Two types of products can minimize the amount of time that doors are left open: walk-in freezer door alarms and automatic door closers. Freezer door alarms detect when the freezer door is ajar and trigger an alarm. The alarm may be visual (blinking or flashing lights) or audible (typical alarm sounds or a voice indicating the door is ajar) or both. These alarms help reduce the amount of time a walk-in freezer door is left open and over time may "train" employees to close the door completely each time they access the freezer. More advanced controllers can also communicate with the refrigeration system, turning it on when the alarm has been triggered to protect product integrity until the door is shut.

Automatic door closers are similar to standard door closers often seen in schools, offices, stores, etc. They feature a simple mechanical device that pulls doors shut. The shut position is usually adjustable so maintenance can find the "sweet spot" within the closer that closes the door completely without slamming it shut. Automatic door closers for walk-in freezers are more rugged than standard units found at the hardware store and most are designed to close a door opened by as little as one inch.

F.2.11 Replace kitchen/deli/bakery appliances with ENERGYSTAR models

The ENERGY STAR label is awarded to products that meet stringent energy efficiency requirements. ENERGY STAR appliances may cost more upfront than their counterparts, but the energy savings on utility bills usually make up for that cost premium. In some areas, utilities may offer incentives for grocers to purchase ENERGY STAR appliances, which also helps eliminate the price differential.

The Food Service Technology Center (FSTC) provides *savings calculators* on its website for a variety of common grocery store appliances. The calculators estimate potential savings for ENERGY STAR appliances as well as total lifetime costs for standard and ENERGY STAR appliances. The *ENERGY STAR Guide for Restaurants* also discusses savings that can be achieved by switching to ENERGY STAR kitchen appliances.

F.2.12 Replace commercial refrigerators, freezers, and ice makers with ENERGYSTAR models

Replacing old commercial-grade refrigerators, freezers and ice makers with new, ENERGY STAR models can save significant energy in grocery stores. Outdated refrigerators and freezers (walk-in or freestanding) may be inefficient due to old compressors, primitive controls, failed door gaskets, poor maintenance and/or improper location. Consider these factors when buying new refrigerators and freezers:

- Get the right size unit for the store's needs and compare models on the basis of expected annual energy use. Using a larger unit than needed will waste energy.
- The higher the energy efficiency ratio for the compressor, the less energy it uses.
- The units should be located so that the rejected heat can be removed by the ventilation system.
- Units should not be located in close proximity to other equipment, such as stoves, that leak heat.

The FSTC *savings calculators* include calculators for commercial refrigerators, freezers, and ice makers. The *ENERGY STAR Guide for Restaurants* also discusses potential savings by switching to ENERGY STAR models for these products. There is currently no ENERGY STAR rating for walk-in freezers and coolers, but a plan for adding these products is in development.

F.2.13 Install variable speed drive kitchen hood exhaust fans with demand control ventilation

Installing kitchen exhaust fans with VSDs allows the ventilation system to respond to the actual ventilation load. These systems use sensors that measure the amount of smoke and particulates from cooking and modulate the speed of the exhaust fan to match the amount of emissions produced. The ideal control system monitors both the exhaust and make-up air fans associated with the kitchen hoods so that proper air balance is maintained. In one FSTC study, a new kitchen ventilation system was installed with VSDs on two exhaust fans and one make-up air unit fan. Without the new system, all three fans ran continuously at full speed, drawing 14 kW during operation. With the new control system installed, the average demand of all three fans dropped to 5.3 kW (Bohlig and Fisher 2004).

In most cases, kitchen exhaust hood systems are equipped with a local override button. If the button is used to return fans to full speed, an alarm should be activated and sent to the appropriate store staff so the cause can be addressed. In most cases, VSDs can improve the control of kitchen temperature conditions and can be integrated into the store's EMS, which constantly monitors the VSD and increases energy savings.

F.3 HVAC: Heating and Cooling

Heating accounts for 56% of an average store's natural gas consumption, while cooling consumes around 15% of electricity. HVAC systems offer many cost-effective retrofit opportunities in grocery stores.

F.3.1 Replace electric resistance furnaces with water source heat pumps

Any grocery store or supermarket using electric resistance furnaces for space heating should consider installing water source heat pumps. Electric resistance furnaces are among the most expensive options to employ for space heating. They basically provide a COP of 1—the heating provided is equal to the electricity used.

For stores with multiple conditioned zones within the building, water-source heat pump systems are a better heating option. ASHRAE Standard 90.1-2010 sets the minimum COP for water source heat pumps at 4.2. These heat pumps take advantage of the building's existing hydronic distribution loop, drawing heat from the loop as a heat recovery system would. And because the heat pumps pull heat from a well-regulated source, they tend to be very reliable and provide consistent heating.

F.3.2 Install an EMS to control, track and report energy use

An EMS provides grocery stores with automatic programmed controls that can manage items such as temperature set points and equipment operating schedules; and can control equipment and scheduling more reliably and precisely than manual controls. An EMS consists of a computer, software to monitor and manage equipment performance and equipment schedules, sensors and controls, and a communications network for larger systems.

An EMS also can provide equipment monitoring data, and track indoor and outdoor temperatures, which allows the operating schedules of HVAC equipment to be controlled based on current conditions. These capabilities save energy, improve comfort, and also trigger automatic diagnostic alarms when equipment is operating outside its correct schedule or temperature set points. Proper EMS programming that is checked to verify functional control of the equipment and energy management strategies is a requirement for effective system performance.

An EMS is most effective when the store's building operating staff is properly trained in how to use the capabilities of the system. It must be monitored regularly to make sure the programmed schedules and settings are up to date and that the energy management strategies are working. Select a system that building staff can be effectively trained to operate, or obtain a service contract to support system operation. One attribute of an EMS is that it does require appropriate operator action in response to some of the data gathered on equipment performance. Operator indifference to, or lack of awareness and response to, significant data provided by the EMS reduces its value as an energy savings strategy. Operator interference or error can compromise system schedules or set points. For example, a temporary change to accommodate a schedule variation that is not reset to its proper settings can result in wasted energy.

The energy savings from an EMS in most commercial facilities, compared to manual operation, is usually between 5% and 15% of total building energy consumption. In retrofit installations, the savings will depend on how efficiently or inefficiently that building was operating before—savings can be as high as 30% for the worst performing buildings (Sustar 2009).

Advances in EMS technology have reduced costs and increased system capabilities. Today's advanced systems take advantage of the internet and communications capabilities to monitor and control multiple stores from a central location.

F.3.3 Upgrade electronic controls

There are two general types of EMS systems: pneumatic and electronic controls. Pneumatic controls, which are uncommon in grocery stores, depend on a properly functioning air compressor and clear air lines (rather than electronic signals), requiring continuous maintenance. Electronic control systems are microprocessor-based controls that use software to perform the control logic functions. Pneumatic controls, found in older systems, do not supply the level of reliability and accuracy that electronic controls provide. Using electronic controls instead of pneumatics can also reduce controls maintenance costs. In addition, the software associated with electronic controls allows for many more energy efficiency strategies than can be implemented with a pneumatic control system.

Even if a store uses electronic controls, new technologies frequently become available that can enhance the degree and accuracy of controls, especially for complex refrigeration and lighting systems. We recommend that energy managers investigate advanced electronic control technologies that can improve the energy savings and reliability of the store's control systems.

F.3.4 Install a dry-bulb air-side economizer (differential enthalpy in humid climates)

When OA is cool enough and there's a demand for cooling in the store, economizers take advantage of the cool outside air to lower the space temperature by opening and closing dampers installed in the air handling equipment. One damper opens up to the outside while the other reduces the return air to the unit; causing the unit to draw in more of the cool outside air (known as "free cooling"). Most of the savings from an economizer system occur during the shoulder months when there is a cooling load and outdoor temperatures and humidity levels are low enough to provide free cooling.

The most common method used to determine if conditions are right for economizer operation is to monitor outside temperature or, in more humid regions, enthalpy (a measure of the heat content of both the dry air and the moisture in it). The proper location of the outdoor air sensor is very important for optimal performance of the economizer. When the system enters economizer mode, dampers adjust based on sensors mounted in the mixed air stream to modulate the return and outdoor air dampers, mixing the two air streams to supply air at about 50°F.

The more OA that can be used for cooling, the longer the cooling compressor can remain off, which saves energy. A properly operating economizer can save as much as 10% of total building energy consumption, with even greater savings in mild, coastal climates (E Source 2006a). Following a new specification for premium economizers can increase savings to close to 20% in favorable climates (NBI 2011). However economizers can increase energy use if they are not properly maintained (see Section E.6.4 for a discussion of economizer maintenance.) A well-maintained economizer can also extend the life of the cooling system by reducing its annual runtime.

The primary limitation of using the economizer strategy is the humidity level of the outdoor air. When relative humidity is too high it can result in excess moisture being brought into the building, resulting in uncomfortable conditions for customers, compromised product integrity, or an increased load on the cooling system.

To determine an economizer's cost effectiveness, conduct an energy analysis that factors in the local climate, OA requirements, and the efficiency of the existing HVAC system. In climates where the OA enthalpy is greater than the RA enthalpy for most of the year, economizers are not likely to be cost effective.

F.3.5 Install a desiccant wheel dehumidification system

Desiccant dehumidification systems offer many benefits over vapor-compression equivalents: reduced cooling loads, improved cooling system efficiency, and improved IAQ. Desiccant dehumidification is an effective application for grocery stores because of the variable cooling loads throughout the building, particularly around the refrigerated and freezer case aisles. Moist air flowing past these cases can cause a host of problems—frost on the doors, frost on the products, fogged-up doors that trigger ASHs, and deteriorating labels and price tags. Desiccant dehumidification systems can reduce the overall humidity within the store more cost effectively than standard dehumidification, helping to avoid all of those problems within the refrigerated and freezer case aisles.

Photo from Mike Farish, Whole Foods Market, NREL/PIX 18616

Figure F–4 Desiccant wheel used for dehumidification at a Whole Foods Market

Standard cooling systems dehumidify supply air by running it across an additional cooling coil. This type of dehumidification requires a coil that is cooler than what's necessary for sensible cooling. This leads to extra energy use at low-load conditions where only dehumidification is needed, but cooling is not. In addition, most systems will have to reheat the air leaving this dehumidification coil because it is too cold for indoor occupants.

Desiccant dehumidification gets around these issues by dehumidifying the air separately from the cooling system. Desiccants are materials that actively attract water. Desiccant wheels incorporate these materials and use them to dehumidify supply air. Typically, the wheel will rotate and desiccants will be exposed to two different air streams: the supply air stream used for the interior of the store that will lose moisture to the desiccant wheel as it passes through; and a secondary warm, dry air stream used to regenerate the desiccant materials, essentially making them "thirsty" again for the next pass through the supply air stream. In large commercial buildings, desiccant dehumidification systems can reduce HVAC electricity use 30%–60% and peak electricity demand by 65%–70% (E Source, 1997).

F.3.6 Add refrigeration system heat recovery coils for hot water or space heating

Refrigeration system heat recovery coils use a heat exchanger to capture heat from the condenser—heat that would otherwise be exhausted to the outdoors. Instead, this heat can be captured and used for other processes like space and water heating. Heat recovery also reduces the workload across the compressor by removing excess heat, thus providing additional energy savings. In one FSTC study, a heat recovery system tied to a walk-in freezer refrigeration system was used to heat incoming city water. The study found that gas use was reduced by 417 kBtu per day and electricity from compressor energy savings was 5 kWh/day. These savings came from a heat recovery system that captured 43% of the rejected heat from the refrigeration system (Zabrowski et al. 1993). In a simulation study conducted by PNNL, a model was designed to use heat recovery on a walk-in freezer refrigeration system for water heating. PNNL's model predicted that on average, the heat recovery system would provide 3,250 Btu/hour to the domestic hot water system (Zhang et al. 2010).

F.3.7 Replace inefficient motors with right-sized NEMA premium efficiency

Motor efficiency is the ratio of mechanical power output to the electrical power input and is usually expressed as a percentage. Improvements in the design and the use of higher quality materials enable premium efficiency motors to accomplish more work per unit of electricity used. Additionally, premium efficiency motors have longer service lives, longer insulation and bearing lives, lower waste heat output, and less vibration, which are features that increase the reliability of motor performance. Many motor manufacturers also offer longer warranties for energy efficient models.

It is usually a good idea to retain a professional engineer to assist in a motor replacement project, because projects typically involve more than just a one-for-one swap of old motors for efficient motors. For example, the most common reason for motor replacement is that the existing motor will not accept VSD control. While it is important to use a premium efficiency motor in a VSD system, it is even more critical to appropriately size the motor to the load. In many stores, old motors were oversized in the original design and therefore can be replaced by motors with lower horsepower ratings.

High-efficiency motors may also run somewhat faster than standard motors. When powering loads such as fans or pumps, the higher speed can result in increased energy use. To avoid this, have the engineer match the motor speed in rotations per minute as closely as possible when replacing a standard motor with a high-efficiency one, or compensate for the increased speed by adjusting fan sheaves or trimming pump impellers.

The economics of motor replacement depend upon the age, condition, operating hours and size of the existing motors and the electricity cost for motor operation; however replacing a standard motor with an energy-efficient motor is usually only cost-effective once the standard motor has failed. To be considered a premium efficiency motor, its performance must equal or exceed nominal full load efficiency values established by the *National Electrical Manufacturers Association* (NEMA 2011).

F.3.8 Convert constant volume or dual duct air handling systems to variable air volume

Constant volume fan systems often waste energy by moving excessive amounts of conditioned air to maintain zone set point temperatures. By installing VSDs on fan motors, the speed of the motors can be controlled so that the system provides only the appropriate amount of air to meet the space temperature and ventilation needs. As the amount of air volume moved by the fan system decreases, the amount of electrical energy required decreases dramatically; and less air needs to be heated or cooled. Savings from a VAV system will depend on building and climate variables—a properly designed VAV system can be expected to save 10%–21% on energy costs compared to a constant volume system (EPA 2000).

The VAV approach allows individual zone temperature controls, proper OA ventilation rates, better temperature control, quieter operation, and energy efficiency—all attractive benefits for grocery stores. VAV systems are very robust and flexible, and with the appropriate dampers in place, they can adjust to the indoor conditions to provide the proper volume and temperature of air to satisfy the heating or cooling load in the space. As the temperature reaches individual set points, the air volume adjusts to its preset minimum flow to provide the necessary ventilation to the space.

Potential disadvantages of VAV systems include inadequate air circulation at low loads and poor reliability due to inadequate maintenance and increased complexity of controls. These systems are most economic when the system that was replaced was an oversized constant volume system with excessive run times.

F.4 HVAC: Ventilation

Ventilation does not consume a large amount of energy in supermarkets compared to other end uses. However, ventilation is critical for IAQ, and systems must be designed to meet the ASHRAE 62.1 air requirement standards for commercial buildings. Correctly sizing the system and upgrading to energy-efficient fans will improve efficiency, especially when other improvements have been made that affect the loads.

F.4.1 Upgrade to demand control ventilation to reduce outdoor airflow during partial occupancy

In large spaces common to grocery stores and supermarkets, the level of occupancy is highly variable. This results in a very large range in the required OA ventilation rate. The amount of fresh air required for a grocery store is much different during busy periods such as the evening rush hour versus the lightly occupied periods late at night or early in the morning. Installation of a DCV system that varies the ventilation based on occupancy can be a substantial energy saver because the amount of OA that must be heated or cooled is reduced during hours of low occupancy. It also reduces the need to manage the humidity impacts of excessive amounts of outdoor air ventilation. DCV systems can offer retail facilities savings as high as $1/ft^2/yr due to occupancy fluctuations (E Source 2006b).

Individuals produce carbon dioxide (CO_2) when they breathe, which when measured, provides a reasonably good indicator of the number of people in the space. As the CO_2 level rises, indicating an increase in the number of occupants in the space, the amount of OA increases to provide the appropriate amount of ventilation required by code. One effective strategy is to locate CO_2 sensors in the return duct for the air handlers that serve those spaces. More sophisticated systems can sample air from several locations and calculate a weighted average of the CO_2 concentration in each zone. The CO_2 sensors should be self-calibrating so they maintain accuracy over time. The readings of CO_2 levels can also be integrated into an energy management system, which provides control signals to the ventilation equipment.

Today's high-quality CO_2 sensors are very durable and require little maintenance. However, periodic testing to verify the calibration of CO_2 sensors is advisable. The primary variables that determine cost-effectiveness are the relative costs of heating and cooling, and the amount by which outdoor air ventilation can be reduced in the controlled zones.

F.4.2 Add energy recovery to ventilation system

Energy recovery ventilation (ERV) exchanges heat and humidity between incoming outdoor air and exhaust air, so that less energy is required to heat or cool the building. ERV is typically done with a rotating energy recovery wheel, which rotates between the exhaust air and supply air within an ERV cabinet. Installing energy recovery ventilation equipment can reduce infiltration of air contaminants from the outdoors while significantly reducing HVAC energy loads (EPA 2003).

In winter, as exhaust air passes through the ERV, its energy is captured and transferred into the incoming air stream to heat and humidify the incoming air to bring it closer to required indoor air conditions. This action reduces the load on the heating system. When cooling is required, heat and humidity are captured from the OA and transferred to the cooler and drier exhaust air as it passes through the ERV. This process reduces the energy consumed by the cooling system. Using an ERV to reduce the load on the HVAC system also reduces the heating and cooling capacity needed, allowing the store to buy smaller units when it is time to replace the heating and cooling equipment. An ERV can also improve IAQ through humidity control.

The economics of ERV depend on how much energy can be saved in both the cooling and heating modes. Energy recovery wheels are designed to last for the life of an HVAC system with minimal maintenance. ERVs should not be installed in proximity to any rooftop sources of pollution (e.g. plumbing vents, exhaust fans).

F.4.3 Install variable speed drives for HVAC supply fans and adjust the ventilation rates as needed to meet ASHRAE 62.1 recommendations

Installing VSDs on ventilation fan motors allows for the speed of the motors to be controlled so that the system provides only the appropriate amount of air to meet the space ventilation needs. As the amount of air volume moved by the fan system decreases, the amount of electrical energy required decreases dramatically, and the amount of energy needed to heat or cool the air decreases as well.

ASHRAE Standard 62.1 calls for minimum ventilation rates in supermarkets to be 15 cfm per occupant and most codes will follow the ASHRAE guidelines. These ventilation rates are critical to maintaining healthy IAQ. Building staff should set HVAC equipment to supply the minimum necessary ventilation rates. These rates are determined by a baseline ventilation rate called for by local codes plus the required load based on building occupancy. However, this method is not ideal as occupancies change and certain spaces go unoccupied for certain periods of time, meaning these spaces will sometimes experience unnecessary and excessive ventilation. Another option for stores is DCV systems, as discussed earlier in Section F.4.1.

F.5 Additional Measures for Consideration

The preceding measures have been identified by industry experts as the most likely to be significant energy savers, cost effective in a variety of situations. But many other retrofit measures have the potential to provide strong financial returns under the right circumstances. Every grocery store has its own unique opportunities, and users of this guide are advised to keep an open mind about specific building improvements to consider. Several additional ideas for retrofit projects are listed in Table F–3. Many other possibilities can be found in the various guides and handbooks listed in Section 4.7.

Table F–3 Additional Measures That Should Be Considered

System	EEM Description	Analysis Performed in Example Building?
Lighting	Replace standard T-8 fluorescent lamps with high-efficiency T-8	No
	Replace metal halide exterior lighting with LED for façades and parking lots, with photocell control	Yes
	Install specular reflectors and de-lamp	No
	Replace lighting system with a more efficient approach (reduced ambient light, greater use of accent lighting, indirect T-5 fixtures in place of direct T-12 fixtures) Institute a "green purchasing" policy (replacement with ENERGY STAR at end of useful life)	No
Plug & process loads	Institute a "green purchasing" policy (replacement with ENERGY STAR at end of useful life	No
	Replace electrical transformers with right sized, higher efficiency models	No
	Install make-up air units and heat recovery system for kitchen exhaust hoods	No
	Replace hot food holding cabinets with insulated, doored holding cabinets	No
Refrigeration	Mechanical subcooling in refrigerated cases	No
	Replace standard low-temperature reach-in and coffin cases with more efficient doored reach-in cases	No
	Replace medium temperature open cases with high-efficiency doored cases	No
	Add heat recovery from refrigeration process and kitchen drain water to pre-heat service hot water	No
	Implement floating head pressure and floating suction pressure controls	No
Building enclosure	Add reflective roof covering (hot climates only)	Yes
	Add continuous roof insulation	Yes
	Install vestibules with inner and outer doors	Yes
	Replace windows and frames with double paned low-e, vinyl framed windows	No
Service water heating	Install low flow pre-rinse spray valves in kitchen	No
	Install VSDs on hot water pumps	No
	Install high-efficiency condensing water heater	No
	Add insulation to steam/hot water pipes	No
HVAC	Add evaporative pre-cooling of supply air (in dry climates only)	No
	Supplement DX cooling system with an indirect evaporative cooler sized to meet small and medium cooling loads (in dry climates only)	No
	Replace DX cooling system with more efficient right-sized model with evaporative condenser and enhanced dehumidification	No
	Install DOAS with high-efficiency heat recovery, reducing the heating, cooling, and dehumidification loads	No
	Replace air or water-cooled heat pump with a right-sized ground source heat pump	No
	Install a coil bypass to reduce pressure drop when there is no call for heating or cooling	
	Install pleated or angled filters to reduce pressure drop	No

Appendix G

Integrated Design Principles for Retrofit Projects

This Appendix provides principles of integrated design for more aggressive grocery store retrofits in combination with a comprehensive renovation, allowing a much wider range of opportunities and higher potential energy savings. Recommendations are presented for both the entire store and for individual building subsystems. Integrated design is essential when pursuing an aggressive energy savings target of 50% or more. Much of the material in the following sections was developed for this AERG by Rocky Mountain Institute as part of its RetroFit initiative. A more comprehensive discussion of this process can be found at *www.retrofitdepot.org/*.

G.1 The Right Steps in the Right Order

Investing in greater efficiency and load reduction can actually eliminate significant costs through downsizing, or even eliminating, mechanical systems—an occurrence known as "tunneling through the cost barrier" (Lovins et al. 1999). Take these general steps to reap the greatest energy savings and to realize multiple benefits from single expenditures:

1. **Define the specific end user needs.** What are the needs and services required by the building occupants? Start from the desired outcome(s): think of purpose and application before equipment. Think of cooling, not RTUs; a hole, not a drill; then ask why you wanted the cooling or the hole. How much energy (or other resource), of what quality, at what scale, from what source, can do the task in the cheapest and safest way?
2. **Understand the existing building structure and systems.** Understand and assess the current state of the building. What needs are not being met? Why not?
3. **Understand the scope and costs of planned or needed renovations.** What systems or components require replacement or renovation for non-energy reasons? What are the costs or interruptions to service or occupancy?
4. **Reduce loads.** Select measures to reduce loads:
   – First, through passive means (such as increased insulation)
   – Then, by specifying the most efficient non-HVAC equipment and fixtures.
5. **Select appropriate and efficient HVAC systems.** After reducing loads as much as possible, consider what HVAC system types and sizes are most appropriate to handle these drastically reduced loads.
6. **Find synergies between systems and measures.** Seek synergies across disciplines and find opportunities to recover and reuse waste streams. Through this exercise, you can often realize multiple benefits from a single expenditure.
7. **Optimize controls.** After the most appropriate and efficient technologies have been selected, the focus should shift to optimizing the control strategies.
8. **Realize the intended design.** Tune the OPR and implement M&V and continuous commissioning to ensure realization of the intended design. M&V will also help staff prevent problems, ensure correct diagnosis, and permit monitoring to improve operation and future retrofit work, and to educate employees and customers.

G.2 Lighting (daylighting and electric)

It's caught on quickly over the last decade that efficient lighting doesn't have to look bad. In fact, grocery stores are gravitating toward lighting retrofits as a major opportunity to save energy while improving product appearance and boosting customer experiences. Lighting systems can also play an important role in creating a signature store appearance and setting customer expectations.

There is a wide range of opportunities worth considering in an integrative approach to store lighting. Strategies to reduce lighting energy use and improve product displays extend well beyond lamp upgrades and the use of LED fixtures in refrigerators. Even if you've already recently retrofitted your lighting system, a comprehensive store renovation can provide additional opportunities to make the most of your system. Take advantage of efforts already being invested into the envelope and interior space planning to also dramatically improve daylight and electric lighting performance, enhance light quality and color rendering, reduce heat, and to draw customer attention where you want to direct it most, on the products.

G.2.1 Define needs—identify visual task requirements

The major lighting priorities in stores are to:

- Provide visual comfort to customers and staff depending on the visual tasks at hand.
- Draw visual attention as desired to different products or characteristics of products.
- Create a signature appearance in the store, or enhance the architecture or interior design of a space.

When it comes to visual comfort, more light does not necessarily equate to better vision. Providing a comfortable visual environment is about tuning that environment to specific tasks at hand. The following criteria are just as critical as providing adequate light levels:

- Light distribution: Are light levels pleasantly and evenly distributed throughout spaces, or are there uncomfortable shadows cast or high contrast areas in some aisles or sections?
- Glare and distraction: Is it easy for customers to view products and product literature, and for staff to focus on food preparation, stocking, and other tasks at hand? Or do specific lighting fixtures cause distracting or competing brightness and reflections?
- Light temperature: Is color rendering attractive?

The Illuminating Engineering Society's *Lighting Handbook* provides detailed lighting guidelines to address different visual tasks and priorities in typical grocery stores space types (DiLaura et al. 2011). You can take a light meter into different spaces to get a feel for current light levels and distribution. As a starting point for amelioration, consider the important qualitative visual needs presented in Table G–1:

Table G–1 Qualitative Visual Needs of Grocery Stores

Space Type	Visual Programming Needs
Sales aisles	• Adequate and pleasantly distributed ambient light levels for simple visual tasks, typically wayfinding and evaluating products or product literature. Provide adequate light levels for a variety of customer and staff ages. • Visual highlighting of products or characteristics of products as desired, e.g. color rendering for produce and meat can be especially important. • Ability to minimize glare and distracting reflectances.
Prep areas	• Could require additional task lighting in strategic locations to provide adequate visual clarity for cleaning and preparing food, and for the use of specialized or dangerous equipment.
Point of sale	• Adequate light levels to perform simple visual tasks such as using cash registers, reading and signing receipts, and bagging groceries. Provide adequate light levels for a variety of customer and staff ages. • Ability to minimize glare and distracting reflectances.
Back-of-house/storage	• Adequate light levels for stocking products, and for office-related tasks such as reading, writing and computer work. • Low-contrast visual environment to promote safety. • Adequate visual cues for wayfinding.
Dining areas	• Adequate and pleasant light levels and attractive color rendering. Simple visual tasks include eating and reading.
Exterior parking and back/ sides of store	• Low-contrast visual environment to promote safety. • Adequate visual cues for wayfinding.

Talk to store staff to find out how well these visual needs are currently being met to identify major deficiencies that should be addressed along with energy efficiency.

G.2.2 Design strategies and measures to reduce loads

Take a hierarchical approach to meet the ambient, task, and accent lighting needs in your facility. No single fixture type should do it all. First, provide ambient lighting. Then use strategic task and accent lighting as needed. Thoughtful product selection and design can significantly help to minimize heat from daylighting and electric lighting fixtures, especially beneficial in areas with perishable products.

Optimize passive daylighting

Effective daylighting can not only meet the majority of ambient lighting needs in typical grocery stores, it can improve product color rendering, and add interest and delight to aesthetically challenged spaces. Daylighting can provide welcome fluctuations in light level and color throughout the day, introducing "cheeriness" and a connection to the outdoors in uniform, dreary spaces. There is a growing body of case studies supporting the correlation between improved daylighting and improved sales. In one study conducted by PG&E in a chain of grocery stores: "Skylights were found to be positively and significantly correlated to higher sales."

All other things being equal, an average non-skylit store in the chain would likely have 40% higher sales with the addition of skylights, with a probable range between 31% and 49%. This was found with 99% statistical certainty. After the number of hours open per week, the presence of skylights was the best predictor of the sales per store of all the variables that we considered" (HMG 1999).

Maximize the use of daylight as the primary source of ambient light in regularly occupied spaces, thereby minimizing the use of electric lights. Many existing grocery stores are one-story facilities with small envelope-to-floor area ratios, and high ceilings in a number of spaces. This makes them good candidates for using natural toplighting to meet 100% of their ambient lighting needs. That said, in retrofits, we inherit the pros and cons of the existing building massing, ceiling plenum design and equipment configuration, ceiling height, and window count and placement. The first step is to consider the geometric proportions of the existing spaces in relation to the existing windows and skylights. Then, search for opportunities to improve daylight penetration and distribution throughout regularly occupied areas despite those limitations.

For detailed practical guidance on daylight design in grocery stores, refer to the IES *Lighting Handbook* (DiLaura et al. 2011), *Architectural Lighting* (Egan, Olgyay 2002) and *Commercial Building Toplighting: Energy Savings Potential and Potential Paths Forward* (Lawrence and Roth 2008). Note that daylight levels may vastly exceed the light levels suggested for grocery stores by the IES. This should not be a problem, provided light distribution is pleasant and glare is minimized. When designing for electric lighting, however, you can use the IES light levels for guidance to ensure you are right-sizing the electric lighting system.

Adding or retrofitting apertures

In order to use daylight we must first let it into the building through openings in the envelope such as windows, skylights, or light tubes. If you are already considering a retrofit to sections of the envelope (for example, to add insulation on the roof or exterior walls, or to reconfigure rooftop units and equipment) it could be a good opportunity to piggyback off of required service interruptions or construction to add, resize, or reconfigure envelope apertures. Even if you are not considering a roof overhaul, daylighting could potentially provide significant enough visual benefits and reductions in lighting energy use to warrant consideration.

Toplighting

Toplighting can be a great way to bring daylight into stores with deep existing floor plates. In buildings with disadvantaged orientation, toplighting can provide a second chance to "get orientation right." Unlike sidelight glazing, which is limited by the orientation of the existing façades, toplight glazing can often be oriented as desired to take advantage of the various thermal or visual properties of directional sunlight throughout the day.

When properly designed, only 3%–5% of roof area need be dedicated to toplighting in order to daylight 100% of the adjacent space below. Toplighting devices come in many shapes and sizes, ranging from custom monitors to manufactured light tubes and skylights (domed and flat), some available with tracking devices to track the course of the sun. Factors that can affect your toplighting device selection include: budget, architectural and aesthetic needs, available roof area, ceiling plenum depth and construction, ceiling height, and impacts to envelope performance (solar heat gain and insulation). To select the toplighting device that best meets your needs and addresses your existing building conditions, refer to *Commercial Building Toplighting* (Lawrence and Roth 2008). For budgets or existing spaces/ceiling plenums that cannot incorporate skylights, consider the use of light tubes, especially in prep areas like delis, bakeries, and meat/seafood counters that often have existing suspended ceilings. When bringing daylight to multiple floors below, minimize roof penetrations by bundling light tubes with existing or new vertical shafts, columns, or other multifloor penetrations. In areas with permanent stations, light tubes can be used for accent lighting to draw attention to specific products and displays.

Sidelighting

Balance lighting with thermal performance when sizing and placing windows. Remember, bigger and more are not always better. Consider visual glazing near the point-of-sale to improve both employee connection to the outdoors and boost customer experience upon entry and exit. In other areas, consider the strategic placement of clerestory glazing to bring daylight deeper into the building. The higher the clerestories, the deeper the daylight will penetrate into the store.

Adding or retrofitting exterior shading devices

Exterior shading devices can help control solar heat gain and glare, and intentionally redirect light to ceilings and other interior surfaces for improved distribution. Adding or retrofitting exterior shading devices can help “fix” existing skylights or windows that currently let in either too much or too little solar heat, or compromise visual comfort with excessive glare. Consider structural requirements and limitations of the existing envelope when selecting and detailing exterior shading devices.

Careful glazing selection can also help balance the visual and thermal properties of sunlight entering the building. Glazing measures to consider include: 1) completely switching out glazing, 2) improving glazing performance by adding a second or third pane and/or gas fill, or 3) adding a film to the existing window. Because northern light is diffuse, concentrate your efforts on retrofits to south-, east-, and west-facing glazing where they will have the most advantageous impact on electric lighting and heating/cooling loads.

Opportunities in interior configuration and design

Interior spaces can be shaped and configured to help redirect light, optimize light distribution and illuminance levels, and reduce glare. When changes to skylights and windows are possible, relatively inexpensive interior improvements can help make the most of your envelope investments. Even exclusive of aperture improvements, changes to interior reconfiguration and design can make a big difference in perceived light quality.

Depending on the scope of interior work being considered, your project could take advantage of the following opportunities:

Relocating or reconfiguring program spaces

Are the right areas and merchandise getting access to daylight? As part of reprogramming, consider locating products, sales aisles, and spaces (like dining areas) that could most benefit from daylight to toplit or perimeter locations.

Raising ceiling heights and improving ceiling profiles

Higher ceilings can help redirect and distribute daylight deeper into interior spaces. Typically speaking, the higher the ceiling height, the fewer skylights required for meeting your ambient lighting needs (and the further apart they may be spaced). Refer to *Commercial Building Toplighting* (Lawrence and Roth, 2008) for diagrams illustrating how ceiling height, skylight design and distribution, and aisle placement and orientation work together to create an effective toplighting design.

If you are already planning to reconfigure or downsize ceiling ducts and HVAC equipment, it could be a good opportunity to eliminate any existing dropped ceilings. If only portions of the ceiling can be raised, consider splaying ceiling profiles (down and away from skylights) to reduce contrast and improve daylight distribution from those apertures.

Adding or retrofitting interior light shelves and baffles

Interior light shelves and baffles can make the most of existing and new skylights/windows by controlling glare and redirecting daylight upward towards the ceiling and further into interior spaces. They can be part of the “fix” for skylights and windows that interfere with product viewing.

Adding cut-outs or glazing to interior partition walls

Openings or glazing in partition walls can help perimeter and toplit areas to share daylight with adjacent spaces. Be targeted with interior glazing placement to make the most of your investment. Use clerestory glazing to light the ceiling surface of adjacent spaces. Where audio privacy and physical separation (e.g., for mechanical zoning purposes) are not an issue, leave cut-outs unglazed.

Reconfiguring aisle, display, and furniture layouts

Optimize location and orientation of aisles to improve daylight distribution. Minimize high-contrast shadows by preventing taller aisles from blocking shorter displays. Reconfigure checkout aisles so they sit perpendicular to vision glazing. Relocate registers and register monitors perpendicular to vision glazing to minimize glare for checkout staff and customers.

Improving surface reflectances

Light-colored ceilings, walls, and floors can aid significantly in perceived light distribution.

G.2.3 Bundling measures to capitalize on synergies

The measures listed above should not be considered in isolation. They work together to optimize lighting conditions; in some cases, it won't make sense to pursue one measure without pursuing others as well.

Efficient electric lighting

Only when daylight conditions are inadequate should electric lights be used. An electric lighting system should be functionally capable of meeting all of the grocery store's required lighting needs. In practice, controls (discussed in the next section) should be deployed to dim or minimize electric lights as appropriate to take advantage of daylight.

Provide a hierarchical electric lighting strategy to provide ambient light first, and then accent and task lighting to draw attention to specific products or to illuminate specific tasks as desired. In no situation should accent lights be the sole source of light.

An important metric to track when assessing electric lighting efficiency is your lighting power density, or W/ft^2. With today's technology and design capabilities, your target W/ft^2 should be in the range of 1.0–1.2 for sales areas, and 0.9–1.1 for the overall store (excluding exterior lights).

To quickly determine where you currently stand for different space types, calculate:

$$\frac{\text{[Watts per lamp]} \times \text{[\# of Lamps in room]}}{\text{[Total ft}^2\text{ in room]}} = \text{W/ft}^2 \text{ in space type}$$

Refer to the IES *Lighting Handbook* to identify lighting needs for specific interior and exterior spaces.

Interior lamp efficiency

Two effective ways to quickly and cost-effectively increase electric lighting efficiency are to replace any existing incandescent bulbs with higher efficiency CFLs, and to delamp fixtures in areas that are overlit. (Refer to Section F.1.2 for more details).

In many instances, you can improve light distribution just by moving fixtures around. How many fixtures can you eliminate from efficient lamping and proper spacing alone, and still provide sufficient illumination? Consider mounting fixtures lower to reduce required quantity and wattage. In areas with dropped grid ceilings or exposed ceilings, moving fixtures around can be a very low cost option. In situations where moving fixtures around requires the demolition of parts of all of the existing ceiling, it could make sense to bundle fixture reconfiguration with an upgrade to entirely new fixtures, and simultaneous changes to ceiling equipment configuration and ceiling height to optimize for daylighting.

Interior fixture efficiency

For ambient lighting, you can get to significantly better efficiency by upgrading typical fixtures to T-8 or T-5 fixtures. Be sure to replace all magnetic ballasts with electronic dimming ballasts.

Consider efficient upgrades for specialized fixtures as well. Use LED lighting for refrigerator and freezer cases. This can significantly reduce the heat load on refrigeration equipment, and also significantly reduce lighting loads. Consider mounting LED lights outside of cases; this takes a portion of heat out of the refrigerator and into adjacent occupant spaces which can be uncomfortably cold for customers anyway.

Different merchandising areas will benefit from different accent lighting strategies. For example: Areas with higher ambient lighting levels require little or no accent lighting. Quality-oriented products such as produce or meat may benefit from lower ambient light levels with increased accent lighting.

Interior reconfiguration and design

Interior design can go a long way to complement electric lighting design, just as it can with daylighting design. Consider ceiling height, aisle height and configuration, location and height of interior partitions, and location of prep areas equipment and displays to ensure they work well with the electric lighting design to optimize lighting conditions and minimize contrast.

Exterior lighting

Install more efficient, full cutoff exterior lighting at building façades and parking lots, with photocell controls.

Efficient controls

Proper controls are essential for ensuring that electric lighting is 1) minimized during unoccupied periods and 2) integrated with daylighting to eliminate the unnecessary use of electric lights. Key control strategies are described in Sections F.1.4–6. In addition to these strategies, consider:

Strategic zoning and bi-level switching

Control ambient lighting fixtures separately from task lighting or accent lighting fixtures. Enable bi-level switching to control light fixtures in daylit and perimeter zones separately from non-daylit spaces.

Vacancy sensors

In transient spaces like restrooms, break rooms, and back offices, control lights with vacancy sensors. Vacancy sensors reduce the occurrence of false “on” signals from the sensor when the space isn’t really occupied. Occupants flip a wall switch to turn the lights on; then, the lights automatically turn off when the space is vacant, similar to an occupancy sensor.

Night dimming

At night, people perceive brightness at lower light levels. Enable automated dimming of lights at night to provide improved visual comfort. For example, if the store is illuminated at 75 footcandles during the day, 40 footcandles may be sufficient at night.

Dimming when there is lower occupancy

Lower light levels are encouraged when there is lower occupancy or when the store is closed. Strongly consider reducing warehouse lighting levels by 50% during stocking hours, parking lot lighting by 50% during closed hours, and general store lights by 90%–100% during closed hours.

G.2.4 Climate Considerations

Thermal risks and opportunities

When making changes to apertures, glazing, and shading, take into account impacts to 1) solar heat gain and 2) insulation performance of the envelope. Understand the needs in your local climate and strategize size, type, and location of glazing and shading devices accordingly to reap *intended* side effects. Balance the solar heat gain coefficient (SHGC) and U-value of skylights with visual transmission (T_{vis}) needs to discourage unwanted energy losses. Note: For retrofits where the resulting skylight-to-floor ratio is 5% or less, losses are *typically* small relative to energy savings from reduced lighting loads. (Lawrence and Roth 2008)

Minimize sidelighting on west- and east-facing façades where solar heat and glare are hardest to control.

Façade-specific approach to window and daylight design

Daylight color temperature, height, and controllability vary throughout the course of day, and even between seasons due to the predictable path of the sun. Develop a tailored approach to daylight design that responds to distinct concerns at each glazing façade.

Overcast versus sunny skies

Is your climate dominated by sunny skies or cloudy skies? Even cloudy sky climates can depend largely on daylight to meet lighting needs – but glazing selection, placement, orientation, and shading design could differ in order to meet your goals.

Exterior lighting functionality

Select exterior lighting fixtures and lamps that can function well in your climate type. As a simple rule of thumb: Exterior fluorescents perform best in warmer climates like that of California, Arizona, and Florida. LEDs perform very well in low temperatures.

G.3 Plug/Miscellaneous Loads and Occupant Behavior

Plug and miscellaneous loads represent a significant portion of total grocery store energy use and are typically subject to occupant behavior. There are numerous low- and no-cost solutions, as well as solutions that require significant capital expenditures. A comprehensive retrofit provides an opportunity to consider all measures and perhaps integrate them with other upgrades (for efficiency or otherwise) for greater cost-effectiveness and convenience.

G.3.1 Define needs—what services do the loads provide?

The end-uses of plug and miscellaneous loads in grocery stores generally fall into two categories. The first category is all the electrical devices used in the kitchen and various other places. These devices include food mixers, vending machines and office telephones. The second category is other, which include electrical transformers (the devices that take high voltage electricity from the grid and convert it to voltages appropriate for plug loads and some lighting systems) and other devices that do not fit into the first category.

G.3.2 Design strategy and measures to reduce loads

The approach to addressing plug and miscellaneous loads can be summarized by three steps:

1. Replacing or decommissioning existing equipment
2. Adding plug load controls
3. Educating staff

The cost effectiveness of taking these steps can range from "no brainer" to "consider carefully." Most of the "no brainer" measures were addressed in Sections 3 and 4. This section will focus on some strategies for selecting measures that may not be so cut and dry.

Replacing or decommissioning existing equipment

Many pieces of equipment in grocery stores are not needed, obsolete, and/or inefficient. If the equipment is not needed or obsolete, the answer is simple: decommission it and if necessary replace with something more efficient, preferably ENERGY STAR-certified. If it's inefficient, which is likely if it is more than a few years old, then it should also be replaced.

Adding plug load controls

The purpose of plug load controls is to reduce or completely eliminate energy use when equipment is not being used. Surprisingly, equipment (even small items like cell phone chargers) still use energy when plugged in but not working—a phenomenon known as "phantom energy" use. These "non-essential" items can be wired into an energy management system that turns them off (a more elegant solution than timer strips).

Some additional plug load control strategies can also be very visible aspects of sustainability in grocery stores. For example, vending machine lighting can be controlled to switch on only when a customer approaches it. The customer should recognize that the vending machine is more efficient and only using energy when needed.

Educating staff

Energy-conscious staff can help eliminate phantom energy use through unplugging devices that are not in use. A short educational meeting is often all that is needed to communicate to staff this opportunity.

G.3.3 Climate considerations

Strategies to reduce energy consumption from plug and miscellaneous loads do not vary by climate. However, the effects of reducing plug and miscellaneous energy consumption on other building systems may change by climate, ultimately leading to a different decision as to whether or not to implement the load-reducing measures. Grocery stores located in more temperate climates are dominated by internal gains, and heat gain from plug loads has a much larger impact on peak cooling loads. In these climates, a reduction in plug load power (and therefore internal heat gains) could be significant in terms of downsizing the cooling system.

G.3.4 Leverage a planned facility improvement

It is clearly most advantageous to replace equipment when it is already due for replacement. However there may be other instances that are less obvious. Pay attention to transformers, as it is very cost effective to replace them with ENERGY STAR-certified transformers close to the end of their useful life (25–40 years). Also, if you are dramatically reducing electricity use as a result of the retrofit project, it may be possible to eliminate one or two transformers—saving significant capital cost for replacement

G.4 Building Envelope

The grocery store enclosure serves as a first line of defense against the elements and as a blanket of comfort for the people and goods inside, with an additional burden of serving as a critical aspect of branding. Grocery stores need not be stuck with a poorly performing or poorly constructed building. A comprehensive retrofit is an ideal time to address many façade and roof issues and correct original construction defects, often resulting in an ability to downsize mechanical equipment slated for replacement and to save capital cost. The high performance envelope improvements can also attract more customers and contribute to brand image. Envelope technology and products have evolved significantly since the 1990s, so any store constructed before that period may well be primed for major envelope retrofits.

G.4.1 Define end-use priorities

When it comes to building enclosure, address infiltration first and then thermal performance. Basic maintenance assumes assuring a functionally sealed building against water infiltration, but too often, like a good customer who slowly drifts away over time, air infiltration is allowed free reign after a building reaches a certain age, and sometimes construction defects were present from day one. That doesn't have to happen in either scenario. We recommend, at a minimum, targeting contemporary performance requirements for reducing air infiltration to comprehensively mitigate this common condition. For perspective on current targets, consider that ASHRAE 189.1, intended for high performance building design, currently recommends an air leakage limit that is at least double the allowed air leakage under the very high performance Passive House guidelines (according to sources at The Passive House Institute and LBNL).

Subsequently, setting a priority to improve thermal performance by adding insulation to walls should not come at a cost of creating moisture problems, especially in a grocery store, so approach thermal measures with care. Done correctly, improving thermal performance can be quite effective; done wrong, it can cost a lot of money later (Rose, 2005). Hygrothermal modeling tools like THERM, HEAT2D, and WUFI can inform the decision of when and where to place additional insulation during a retrofit.

G.4.2 Design strategy and measures to reduce loads

As with all major energy retrofit projects, the design strategy should be one of integrative design processes and solutions. Envelope retrofits can have a number of benefits from single expenditures. However, the first step in addressing envelope condition as part of a retrofit should always be investigation; initiate Building Enclosure Commissioning. Where are the weak points in the system? Is there significant room for improvement? Are envelope conditions affecting more than just energy consumption? Is the condition of the envelope affecting sales? This most often includes occupant surveys, monitoring, infrared thermal imaging, and blower door testing, which can reveal all the ugliness in the system.

Walls

The exterior walls of a grocery store are often an important aspect of the brand and are vital in establishing a first impression for new customers in a competitive market. If the store is in need of aesthetic work through a comprehensive retrofit, it's a great time to address performance as well.

Seal the cracks

Addressing infiltration is the highest priority in the envelope system. IRT images will point to areas where air is clearly passing through the walls unintentionally. Most often, these are at joints between walls and the roof or floor, where materials change, and at penetrations such as vents. If accessible, seal the joint areas from the interior of the building with an expandable sealant appropriate for the adhering material. Seal material transitions and penetrations from the exterior and interior. If the store is constructed of masonry, check mortar and expansion joints for infiltration issues. Extensive repointing may be in order, which can significantly extend the life of a building while reducing energy consumption.

Insulate

Thermal performance is most certainly affected by conduction – the movement of heat through material. Adding insulation adds resistance to the movement of heat. In order to create continuous insulation spanning the enclosure, which is highly desirable, installation on the outside of the wall assembly is the most effective. However, this can change the character of the building significantly, which may be part of the plan for image upgrades; but interior options are entirely viable, albeit providing slightly lower energy savings. For stores that need a facelift, consider some of the new high performance insulated façade systems as an alternative to the overused and occasionally problematic synthetic stucco exterior insulation finish system products, although even that may be appropriate in some markets. Again, carefully assess the impacts of adding insulation.

Shade and reflect

Radiation is the most apparent source of heat gain when assessing thermal performance and one of the easiest to mitigate while adding value to the building. There are two approaches to mitigating radiative effects: shade the building and/or reflect the radiation right back into the atmosphere. If you can shade any part of the wall during hot months, do it. If the store needs a facelift on all or a portion of the façade, consider adding a rainscreen, vegetated green-screen, or louvered wall assembly tuned to block the summer sun, and include a radiative barrier if possible within the east and west façade assemblies. Pay attention to exterior finish colors as this can either create a radiative heat sink (good for cold climates) or reflect heat (good for hot climates), depending on the color and reflectivity. Plant deciduous trees near the store (maybe within the sidewalks or medians) on the east, south, and west sides to shade the façade and create a landscape suitable for a seasonal farmers market affiliated with the store. If possible, calibrate, construct and/or extend existing roof overhangs to perform a useful function and shade walls during the hotter months.

Reduce heat island

Heat convection can impact a building envelope in unforeseen ways and is a thread that also ties to radiation and infiltration. That adjacent blacktop parking lot may be affecting cooling loads more than you realize. By creating a pocket of warm air over hard surfaces likely located in close proximity to the store entrance, it is also radiating heat onto walls and creating a source of warm air that infiltrates the building you're trying to keep cool. Is it time to replace the parking surface? Consider concrete or other lighter surfaces – even permeable material. Can you shade the parking surface? Add photovoltaic shade structures or landscaped tree islands to reduce the microclimate temperature. Eliminate the hardscape immediately adjacent to the walls and replace it with high albedo landscaping. This will lower the temperature of those wall surfaces and enhance the building architecturally.

Roof

At any given time of day, the roof is generally the largest area of exposed envelope surface and certainly experiences the most hours of direct exposure to the sun. This can have considerable impact on energy consumption if the roof is deficient. The roof may actually be the most valuable focus for envelope efficiency in a retrofit project.

Seal the cracks

Roof measures to address infiltration are similar to wall measures, but there are usually more equipment penetrations on a roof than the wall, so assess them thoroughly. Seal skylights and light tubes well. If infiltration is indeed a problem at the roof-wall intersection, then consider re-roofing as part of a comprehensive retrofit to completely eliminate the gap, especially if skylights are added to improve merchandising or rooftop HVAC equipment is replaced.

Insulate

Where walls can be problematic regarding added insulation, roofs are a no-brainer. When an energy retrofit coincides with a planned roof replacement, take the opportunity to install additional continuous rigid insulation to the exterior of the roof surface and meet roof insulation recommendations stated in ASHRAE 189.1.

Increase surface reflectance

Roofs take the brunt of the sun's radiation. Installing a reflective radiant barrier beneath roof decking can reduce heat gain by 40% in very hot climates. (Fairey, 1984) Radiant barriers are generally recommended anywhere south of the Mason-Dixon line. If roofing is indeed being replaced, then choose a reflective white or light colored roof to further mitigate the effect of solar radiation on the building. Additionally, the roof is an ideal location for a vegetated surface. New green roof technology has migrated this design element to the forefront of green building features with limited risk for failure if designed by a professional. Vegetated roofs have proven to lower the temperature of a roof microclimate by as much as 80°F on an average summer day, reducing interior cooling load by as much as 20°F (UT Austin, 2008).

Lighter colors and green roofs also create an ideal surface for photovoltaic panels, which operate more efficiently at cooler temperatures.

Doors/windows

Doors and windows are the most vulnerable parts of the envelope. They are often designed to move, so they require tolerances for movement, feature continuous cracks ripe for infiltration, and must be lightweight enough for human control. Modern grocery stores generally feature very few windows; however, some older stores and neighborhood markets still feature curtain walls on the main façade. Not to worry; any building style can be retrofitted.

Seal the cracks

Windows and door openings should be weather-sealed during basic maintenance, but the window and door units themselves often develop gaps where dissimilar materials join – such as at the connection of glass to frame. In a common example of construction defects, windows and doors are too often installed badly, with unsealed or uninsulated voids within the framing itself. It may be worthwhile to reinstall good existing windows and doors if the installation itself is poor. Comprehensive building retrofits are a good time to address all of the windows and doors at once to save on costs. Component systems, such as curtainwalls, are especially repairable and can be resealed or completely retrofit. If the system is irreparable, replace with high performance products that meet ASHRAE 189.1. Additionally, in moderate to cold climates, construct vestibules at primary entrances to reduce air infiltration due to building users coming and going, and rethink that air curtain.

Reduce thermal bridging

In windows and doors especially, thermal bridging within the frame and/or glazing panel can be particularly detrimental to performance. As stated earlier, some existing units can be retrofit, and some cannot. Insulated glazing panels can even be retrofit to mitigate thermal bridging while also addressing radiation (Empire State Bldg, 2011). Older steel windows are particularly challenging.

Shade and filter

In the past, many glass fronted stores addressed excessive window heat gain by applying dark films and installing full height blinds, which block the potential customer from the merchandise on display. Today, spectrally selective window film technology allows us to reject a high percentage of heat (with a low SHGC) while admitting more visible light (high T_{vis}), and it's available in a retrofit product with good warranties. Simple tinted or low-e films do not necessarily achieve the same results, so choose products wisely. Consider adding or restoring awnings and other shading devices when assessing store windows. Imagine the potential of restoring a curtainwall grocery store to its original transparency and style. Exterior window louvers can be designed with the sun's path in mind for real utility, using horizontal slats on the south façade and vertical on the east and west. Often enhancing architectural style while blocking up to 40% of direct sunlight, these simple devices can dramatically improve both sales and energy use. Understand that the solution should differ from the south elevation to the east/west elevations for optimal efficacy.

G.4.3 Climate considerations

As with any architectural decision, each of these recommended measures for consideration should be assessed in its appropriate regional and climatic context. However, across all climates, reducing infiltration is critical, and in hot and humid climates, moisture barriers become extremely important. Put your money and effort there when prioritizing. If the store is located in a cold climate, then a light colored roof may not actually save energy. In some climates, grocery stores are dominated by internal loads, and the envelope becomes a relative non-issue. Also, the insulation of the envelope is much more important in heating dominated climates—it may not be cost effective to add insulation to cooling dominated buildings. In very hot climates, window shading devices and SHGC should be chosen to block even winter sun.

Changing climate should also be considered. Commonly referred to as "global weirding," shifting climate and weather patterns are wreaking havoc on cities both in terms of temperature extremes and high wind speeds. Designing resilient and efficient buildings means we're often meeting the needs of a 100°F summer day and a -7°F winter day in one building, that unless recently experienced a much narrower range of temperatures. Throw in higher wind speeds from increasingly violent storms, and we are compelled to create tight, well-insulated, durable buildings in an effort to stay safe and comfortable.

G.4.4 Leverage a planned facility improvement

Comprehensive energy retrofits, especially staged retrofits, should be timed with major physical improvements to create an integrative opportunity to address whole systems sustainability. This means that aesthetic improvements should also take into account envelope performance improvements. Landscape projects should also reduce building energy if possible. Major retrofit projects for programming or branding purposes should weave envelope efficiency measures into the project scope. Improving daylighting for increased sales and better street presence? Retrofit the curtainwall for energy efficiency.

G.5 Service Water Heating

Service water is often overlooked within the commercial building sector, as it is not typically a significant end use in terms of overall energy costs. However, service water heating retrofits can often be some of the most cost-effective to pursue and should be considered in any retrofit project.

G.5.1 Define needs—specify end use temperatures

Service water heating in grocery stores provides warm or hot water for the following end uses:

- Restroom hand washing at lavatory faucets (minimal consumption)
- General cleaning (includes pressure washers for cleaning cases)
- Food prep area cleaning
- Food prep sink use
- Food prep steamers

First, ask the question: *Is warm/hot water really necessary to satisfy this need?* In some instances, such as general cleaning, cold water may be sufficient. If heating is required, the incoming water from the utility is typically at about 60°F and energy is used to raise that to the desired end use temperature. Consider the needs that must be met, and re-evaluate the water temperatures required. Changing the temperature setpoints is the easiest and most cost effective way to save water heating energy. Evaluate the occupant and end use needs, and specify appropriate temperatures for faucets, spray valves, cooking equipment, and pressure washers.

G.5.2 Design strategies and measures to reduce loads

Retrofits to a service hot water system present a unique opportunity to conserve not only energy, but also water, which is a rapidly depleting natural resource. Some efficiency measures only reduce the energy required to heat the service water, but others save energy by simply reducing the amount of water that is being used. The cost-effectiveness of these measures is heavily dependent on the water utility rates and their expected escalation in the coming years.

Reduce hot water consumption

The largest opportunity for reducing water consumption in grocery stores is for cleaning. The majority of water is use for washing down the cases. Portable pressure washers (2.75 gpm) can replace hose racks (12 gpm) for significant water savings. In the food prep areas, specify low-flow spray valves at 1.6 gpm. Also, many food prep areas have a need for steaming food. Switch to boilerless steamers which use 2 gal/hr instead of the typical 20 gal/hr. In restrooms, install aerators to reduce flow in lavatory faucets to as low as 0.5 gallon per minute (gpm). If you are able to replace the faucets, specify sensor-controlled or timed electronic faucets with automatic shut-offs.

Reduce energy for water heating

Once you have reduced the amount of water being used, you can tackle the energy required for heating. Make sure you are covering the basics by addressing heat loss and controls. Minimize the standby heat losses from distribution piping storage tanks by increasing insulation, and using anti-convection valves and heat traps. Use recirculation timers to control the circulation of hot water based on demand.

On the equipment side, consider tankless on-demand water heating for restroom hand sinks and refrigeration waste pre-heat for kitchen and cleaning uses.

G.5.3 Climate considerations

In general, most service water heating retrofits will be more cost effective in colder climates, particularly those that minimize standby heat loss. Because the mains temperature is lower in cold climates, more energy is required to heat it. The cost effectiveness of solar thermal systems is highly dependent on the amount and regularity of solar radiation on site. When considering solar thermal systems, carefully study the amount of available solar radiation and the freeze protections requirements.

G.5.4 Leverage a planned facility improvement

Often there are planned facility improvements that can make additional energy retrofits more cost effective. Is the roof being replaced? This is an excellent time to install roof mounted solar thermal collectors. Are the food prep areas being updated or reconfigured? Install low flow fixtures for cleaning and food prep.

G.6 Refrigeration

Refrigeration is most often the single largest end use in supermarkets, so a few improvements in the system can go a long way toward reducing total energy consumption.

G.6.1 Define needs

As always, the first step is defining your needs. Usually, the top priorities are keeping food cold to prevent spoiling, and showcasing the products for sale. Once you have defined your needs, select the most efficient system to achieve them. Oftentimes, there is an equally viable way to attain the goals of a system that uses significantly less energy.

G.6.2 Design strategies and measures to reduce loads

Add doors or night curtains to cases

Adding doors to cases is the single best way to reduce refrigeration loads. Whether you are completely replacing cases or just retrofitting, doors are always cost effective because the reduction in total load is about 80% for vertical multideck cases. If it is not feasible to add doors, then consider adding night curtains to open cases to reduce refrigeration loads during unoccupied hours.

In addition to reducing refrigeration loads, adding doors or night curtains also reduces the cooling effect of cases to the space, which is known as "case credit." Unfortunately, case credit is hardly ever a credit, but a penalty. This cooling effect forces the HVAC system to provide much more heating than necessary in heating mode. And, although case credits help the HVAC system cool the space when needed, they do so less efficiently because the refrigeration compressors are less efficient than the HVAC compressors.

In the past, many supermarkets have resisted adding doors, even though they recognize the possibility for large energy savings, because they fear a reduction in sales. However, a recent study funded by ASHRAE (Fricke & Becker, 2010) showed that doors had no effect on sales.

Reduce internal gains in cases

The next best way to reduce refrigeration use is to reduce internal gains. This can be accomplished through the use of more efficient fixtures such as LED lights and electronically commutated fan motors, as well as by implementing advanced control strategies such as using timers to switch lights off during unoccupied hours or using motion sensors to switch lights on only when customers are present. In a recent Wal-Mart case study, the combination of replacing fluorescent lights with LEDs and adding motion sensors was shown to reduce case lighting power consumption by 67% (Watt Stopper/Legrand, 2007).

Additionally, for each 1 kWh reduction in internal load, another 0.3-0.5 kWh is saved in refrigeration compressor energy.

Optimize controls for part load conditions

Refrigeration systems run at part load for the vast majority of the year. If you are not running your system at a reduced level, you are missing out on easy savings. Head pressure reset can be combined with electronic expansion valves to lower minimum condensing temperatures to 50°-60°F, and a VSD should be added to the condenser fan to take advantage of part load conditions.

Recover waste heat

In order to keep cases cold, the refrigeration system creates an extraordinary amount of heat, which can easily be recovered for space heating, service hot water heating, or even for more innovative purposes such as liquid desiccant recharging in a dehumidification or indirect evaporative cooling system.

Heat recovery systems are most easily used to capture heat in the form of hot water. It is generally cost effective to pre-heat 100% of the service hot water using recovered waste heat in any supermarket.

Space heat recovery is also very effective for air-based HVAC systems when there is a long heating season or a large refrigerated case cooling effect.

Specify efficient systems

Once you have reduced loads as much as possible, be sure to design an efficient system. Obviously, high efficiency compressors can save energy, but there are also ways to configure the system in order to gain efficiency. For instance, use liquid sub-cooling to shift load from low temperature compressors to more efficient medium temperature compressors.

If you are replacing the refrigeration system entirely, consider alternative systems that use secondary loops or non-HFC refrigerants. The International Energy Agency (2003) has sponsored studies of several alternative systems.

G.6.3 Climate considerations

Climate is less influential on refrigeration systems than on HVAC or the building envelope, but some factors do come into play. In dry climates, it is easy to use evaporative condensing to lower condensing temperatures. Also, heat recovery systems should be designed with the climate in mind. In hot, dry climates it may not be worth an air-side heat recovery coil for space heating due to fan static pressure penalties. In humid climates, desiccant dehumidification can offer a good return when you have a large waste heat source from refrigeration.

G.6.4 Leverage a planned facility improvement

Be sure to take advantage of a planned upgrade. If you are in need of new cases, consider switching from open to doored cases with more efficient fans and lights and smarter controls. When packaged together, these upgrades become significantly cheaper than when done piecemeal. If you are reconfiguring the layout of the store, try to reduce refrigerant line runs. This will save capital costs, reduce refrigerant leaks (which are greenhouse gases or ozone-depleting substances, or both), and save energy.

G.7 Heating, Ventilation, and Air-Conditioning

HVAC systems present unique challenges within grocery stores. They must provide thermal comfort and adequate ventilation air for the occupants, while often competing with the refrigeration systems. Infiltration of cold air from freezer aisles becomes a heating load for the HVAC system. Further, humidity control is particularly important in grocery stores as rrefrigerated case loads are very sensitive to humidity. High humidity can cause frost buildup and condensation on display-case doors.

Packaged rooftop units are by far the most common HVAC systems used in grocery stores, but they are rarely the best choice. DOASs are becoming more common due to the unique dehumidification needs.

G.7.1 Define needs—specify temperature, humidity and outside air

HVAC systems affect the occupant's thermal comfort and maintain food freshness by controlling the temperature and humidity of the air. In grocery stores, the requirements for food freshness dictate the set points, and the environment is often colder than would be designed for human thermal comfort. The most cost effective way to reduce energy for HVAC systems is to expand the allowable ranges for indoor temperature and humidity. Carefully study the environmental requirements of the food products in each space type, and determine acceptable ranges for temperature and humidity within each space.

Next, consider the amount of ventilation air required by the building occupants in each space type. Ventilation air is also required to prevent mold growth from unwanted moisture accumulation. Conditioning outside air is one of the most energy intensive jobs that an HVAC system performs – the first step is minimizing the amount of outside air that needs to be conditioned. Calculate the required exhaust and ventilation air according to ASHRAE Standard 62.1, using the actual occupancy rates as opposed to the default occupancies provided in the standard. As the default values are very conservative, this simple step can sometimes reduce the amount of outside air by over 30%, saving energy and also reducing the size the of system required. Carefully consider the amount of ventilation air required for mold growth and investigate other less energy-intensive ways of preventing mold.

G.7.2 Design strategies and measures to reduce loads

System sizing and selection

Evaluate heating and cooling system options only after the loads have been drastically reduced from other retrofit measures (namely refrigeration measures). These reduced loads can sometimes change the appropriateness of various system options. When choosing a system type, consider the following:

- Extent of Renovation: In a major renovation, there is often an opportunity to completely replace the HVAC system. If the renovation is not a complete gut, it's rarely cost effective to completely change the air and water distribution systems, so this would dictate the system options available.
- Climate: What system types can best capitalize on the climate characteristics of your site?
- Outside Air: What is the best way to condition the outside air? Because of the dehumidification requirements in grocery stores, it is a good strategy to decouple the ventilation load from the sensible cooling load through a dedicated outdoor air system. With the amount of waste heat available from the refrigeration systems, consider desiccant dehumidification with waste heat regeneration.
- Zoning: If the interior space is being reconfigured, place refrigerated cases and food prep areas in locations that facilitate heat and energy recovery. Radiant floors are an excellent solution that can be separately controlled to warm up cold aisles while cooling other areas.

Finally, right size the chosen systems. Accurate sizing of equipment leads to lower equipment costs, lower utility costs, better dehumidification performance, and more comfortable conditions. Be sure to take into consideration the cooling effect of refrigerated cases and any load reduction controls that are in place, such as daylighting sensors.

Specify efficient equipment

Once the systems have been chosen and sized, specify equipment with high peak and part load efficiencies. Consider VSD compressors and high efficiency fans, motors, and pumps. Selecting an efficient method for dehumidification is also key to any grocery store HVAC renovation. Part load performance is just as important as the rated efficiency, so carefully consider performance curves when choosing equipment.

Optimize distribution design

In a major renovation, there is sometimes an opportunity to overhaul the existing air and water distribution systems. This translates into very significant fan and pump energy savings. Low-energy use ductwork and piping design involves short, direct, and low pressure drop runs. Minimize the number of fittings and design for the least amount of turbulence possible. In grocery stores, there is a unique opportunity to save energy by pulling HVAC return air from under refrigerated cases. Finally, make every effort to group exhaust air streams together to facilitate sensible heat or energy recovery with outside air.

Optimize controls

Optimizing HVAC controls is a cost effective energy saving strategy and is a key component to any comprehensive retrofit. In grocery stores, the most important aspect of this is controlling the amount of conditioned outside air. Use electronic control systems for greater accuracy, performance, and energy savings and incorporate this data into a BAS that the facility manager can use to operate the building. Carefully coordinate HVAC and refrigeration control strategies. Some of the most common and profitable control strategies to consider for grocery stores include:

- Off Hours Controls: During unoccupied periods, employ temperature setbacks and do not bring in any outside air.
- DCV: With DCV controls, you can control the amount of outside air being provided to each zone based on the occupancy. CO_2 sensors should be used as grocery stores can have highly variable occupancy patterns.
- Economizers: Consider the use of either an air-side or water-side economizer to capitalize on “free cooling.” Should the economizer be controlled based on air temperatures or enthalpy?
- Exhaust: Grocery stores often have a significant amount of exhaust from kitchens and food prep areas. Consider VAV exhaust with heat recovery.
- HVAC Controls: Develop an overall controls strategy for the HVAC system that includes VSDs, equipment sequencing, water temperate resets, soft-starting of motors, and DCV.

Recover and reuse waste streams

As noted in the refrigeration section, the heating loads in grocery stores, which are exacerbated by refrigerated cases, can be partially offset by using waste heat from the refrigeration system for space heating.

Additionally, heat or energy recovery should be considered for outside air and exhaust streams. In larger applications, a combined heat and power plant may make sense, with micro-turbines, and heating as needed from waste heat.

Bundle measures to optimize synergies

Always consider interrelated measures and which should be implemented together to maximize savings and return on investment. For example, any renovation to the refrigeration systems should be bundled with heat recovery for space and service water heating.

G.7.3 Climate Considerations

The loads within a grocery store are driven by internal gains from occupants, lighting, and refrigerated cases, and the building envelope is less important in terms of heating and cooling loads. However, climate considerations do have a significant impact on the amount of energy required to condition outside air. While DOASs are a good application for grocery stores in any climate, the method of cooling and dehumidification will vary by climate, as will control strategies (e.g. enthalpy based controls in humid climates).

Generally speaking, it is valuable to:

- Address the thermal risks and opportunities in the climate: Is indirect evaporative cooling the best method for conditioning outside air? Can nighttime ventilation pre-cool the building?
- Evaluate contributions to peak heating and cooling loads. Is this building dominated by heating or cooling loads? Sensible or latent loads? Is the climate (i.e. envelope loads) a major factor or are the loads driven by internal gains?

G.7.4 Leverage a planned facility improvement

Often there are planned facility improvements that can make additional energy retrofits more cost effective. If major capital equipment, such as an RTU, is nearing the end of its useful life, this is an ideal opportunity to redesign and resize your HVAC equipment. Are changes to the utility rates being considered? Evaluate the cost effectiveness of peak shifting thermal storage systems on a time of use rate. Is the interior space being updated and reconfigured? Consider rezoning to maximize heat recovery opportunities.

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