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SYNTHESIS 21

AIRPORT
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PROGRAM

Airport Energy Efficiency and Cost Reduction

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A Synthesis of Airport Practice

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ACRP SYNTHESIS 21

Airport Energy Efficiency and Cost Reduction

A Synthesis of Airport Practice

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

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Cover figure: Deep overhangs, integrated shading devices, and tinted, insulated glass reduce heat gain and cooling loads while allowing daylight to flood the main concourse at MSP Terminal 2 (Humphrey Terminal). (Photo Credit: Miller Dunwiddie Architecture, Minneapolis, MN.)

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
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This report documents energy efficiency improvements being implemented at airports across the country that are low cost and short payback by means of a survey, interviews, and a literature review. It targets small airport terminal managers, staff, consultants, and other stakeholders interested in energy efficiency.

Craig R. Lau, Joel T. Stromgren, and Daniel J. Green, Miller Dunwiddie Architecture, Minneapolis, Minnesota, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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AIRPORT ENERGY EFFICIENCY AND COST REDUCTION

SUMMARY

This report documents energy efficiency improvements being implemented at airports across the country that are low cost and short payback by means of a survey, interviews and a literature review. It targets terminal managers of small airports, staff, consultants, and other stakeholders interested in energy efficiency.

The literature review was undertaken to identify best practices for energy efficiency in commercial buildings to generate categories and questions for the survey about low-cost practices and where they may have been implemented. In addition, the review collated data from previous studies about low-cost energy efficiency improvements. Following the survey, another literature review was performed to elaborate on survey findings. The survey included questions related to energy efficiency planning and project identification, project implementation and funding, and improvements to major mechanical and electrical systems. Twenty survey responses (a 100% response rate) were received from airports representing large and medium hub, small hub, non-hub, and commercial service U.S. airports.

All airports responding to the survey had implemented at least one type of low/no-cost energy efficiency improvement, usually lighting retrofits. Following the survey, airports describing multiple energy efficiency projects were contacted and interviewed to provide more precise information and background about the improvements. A total of 12 airports participated in follow-up interviews.

Both the literature review and interview feedback indicated that data collection is paramount to most improvements. Without an energy audit or building automation system information determining where energy efficiency projects will have the greatest impact on energy costs is challenging. In addition, continued tracking of data will allow new and existing systems to be monitored for trends and payback information. Therefore, building automation system installation and/or upgrades may be considered high-priority projects to provide accurate, useable data. In addition, low-cost, utility-sponsored energy audits are a valuable source for data.

Operations and maintenance practices such as performance monitoring and commissioning were common among respondents and often had short payback or low cost. This feedback supports best practices that outline commissioning, maintenance scheduling, staff behavior, and intra-airport communication as keys to successful energy cost reduction.

Retrofit of mechanical systems is commonly associated with high costs and potentially long payback. However, as with lighting systems and building automation, respondents found that for most mechanical systems significant advances in efficiency have been made since components were first installed at their facility. When replaced or re-commissioned with new controls, major reductions to energy expenses were found.

For many respondents, funding was identified as a major barrier to implementation of energy efficiency improvements. Implementation tactics varied for those airports that have successfully reduced energy costs. Small airports may work to include energy efficiency into

operations and maintenance programs but cannot maintain dedicated funding from year to year. Major airports, especially those with demonstrated energy savings, had dedicated program and Capital Improvement Program funding as well as a backlog of identified projects.

Major airports have the size, budget, and staff complexity to test energy efficiency operations and retrofit projects and may be used as a reference for smaller airport terminals—information can be shared and many energy efficiency ideas are scalable. Communication within and between airports is encouraged by literature sources and survey responses.

In many regions, utilities serving airports have become partners with airport operators to assist in conducting no-cost or low-cost energy audits and in providing grants or rebates for demonstration projects or energy efficiency upgrades. Many of these utility incentives, along with government incentives, can be found in one location: the Database of State Incentives for Renewable and Efficiencies (http://www.dsireusa.org/summarytables/finee.cfm).

When funding or costs have proven a challenge to implement a program, airports have leveraged energy efficiency dollars by partnering with other existing county or city projects.

Airports may be distinctly positioned to use renewable energy technology owing to their high roof surface area relative to total building square footage and large areas of open land within airport campus boundaries. Major utilities and energy service companies are beginning to implement large-scale photovoltaic system installations on existing buildings and sites though power purchase agreements and other programs.

The diversity of strategies and relative costs noted in the survey response asserts that no two airports are equal; nor will they benefit the same from any improvement. The best reference for an airport terminal can be found in baseline conditions that exist today on site.

No further research is identified at this time other than monitoring airport energy efficiency improvements and updating synthesis of practice as new tools or regulations warrant.

CHAPTER ONE

INTRODUCTION

The report presents analysis and findings from the survey data and interview summaries collected on airport energy efficiency practices at small airport terminals. It includes details of the literature review, a discussion of data and analysis related to topic areas, conclusions drawn from interview data and other information reviewed, as well as a chapter on new technologies and innovation.

AUDIENCE AND DISSEMINATION

This synthesis specifically targets terminal managers and staff of small and medium-sized airports. The report seeks to capture and document successful energy efficiency practices and attempts to quantify relative costs and payback time frames for further reference and planning. The goal of the report is to identify real, implementable actions that will result in reducing energy consuming system costs in small terminals.

The report is meant to be an easy-to-use reference document for airport terminal managers, operations and maintenance (O&M) staff, aviation design consultants, and members of the public with an interest in airport terminal energy efficiency.

BACKGROUND AND PROJECT SCOPE

Airport terminals use large amounts of energy for lighting, heating, ventilation, air conditioning, and conveyance systems; within the United States, buildings account for 40% of all electrical energy used. Some airport operators have reduced operating expenses by focusing on energy efficiency, considering both energy supply and energy consumption. Some airports have used terminal roofs or land areas to host alternative energy systems. Many airports have eliminated unnecessary energy use in airport facilities as a way to reduce operating expenses. This synthesis will focus on selected opportunities by describing successful practices that airports have implemented to increase energy efficiency and reduce operating costs at airport terminals.

TERMINOLOGY AND KEY DEFINITIONS

As defined by the U.S. Department of Energy (DOE)—Energy Information Administration (EIA), "an increase in *energy efficiency* is when either energy inputs are reduced for a given level of service, or there are increased or enhanced services for a given amount of energy inputs" (EIA–DOE 2003, paragraph 3). For the purposes of this report, inputs are considered to be electricity supplied by a power plant either within the airport boundary or supplied by a local utility company and fuel sources used to create electrical energy.

Simple *payback* was found to be a common method of determining feasibility for energy efficiency projects in initial literature reviews and was used as a metric within the airports survey. Simple payback can be defined as the years required for improvement to return savings equivalent to project costs.

ISSUES ADDRESSED

More than two decades ago, the Bruntland Report, issued by the United Nations, identified buildings and energy efficiency as major areas to save energy resources. Today, reports continue to echo the benefits and potentials of efficiency, including what could be described as its minimal environmental impact and ability to "displace costly and disagreeable energy supplies, enhance security and prosperity, speed global development, and protect Earth's climate—not at cost but at a profit" (Lovins 2004, p. 384).

According to Amory Lovins of the National Renewable Energy Laboratory, "energy efficiency is generally the largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services" (Lovins 2004, p. 384). However, it does not receive fair consideration, both in terms of realized savings and potential. Indeed, "the potential of energy efficiency is increasing faster through innovative designs, technologies, policies, and marketing methods than it is being used up through gradual implementation" (Lovins, pp. 384–385). When understood in this regard, energy efficiency can even be considered an untapped "resource" such as solar power, able to increase existing capacity and bank power for future projects.

The focus of this synthesis is on identifying and listing ways to reduce energy costs at small airports through energy efficiency. Specifically, the survey, literature review, and interviews focus on the following categories and subcategories developed by the synthesis team:

- Energy efficiency in airport operations and capital improvement planning, especially
  - Methods of identifying and categorizing energy efficiency projects and
  - Resources available to airports for planning and execution of energy efficiency projects.
- Energy efficiency practices that can be implemented at low cost, specifically
  - Practices related to energy management through improved O&M,
  - Improvements targeting energy use by building systems and sub-systems, and
  - Methods of energy conservation related to building enclosures.
- Strategies concerning implementation of energy efficiency projects including
  - Factors that aid in implementation and
  - Challenges to implementation.
- Emerging technologies, long-term payback improvements, and policy direction of note, specifically
  - Mechanical and renewable technologies,
  - Emerging project delivery methods for high-performance buildings, and
  - Federal policy concerning energy efficiency.

REPORT CONTENT

The report is structured in a manner that will aid in the determination of energy efficiency projects and resources. After discussion of planning processes, practices are divided into chapters concerning operations, systems, and conservation. At the end of each practice chapter, practices are summarized in a chart. Next, implementation factors and a brief discussion of emerging technologies are followed by conclusions and appendices including the report methodology and survey questionnaire. A comprehensive chart outlining systems and operational strategies for increasing energy efficiency and reducing energy costs concludes the appendix.

For more information on the report, survey, and interview methodology see Appendix A.

CHAPTER TWO

PLANNING FOR ENERGY EFFICIENCY

This synthesis identifies practices and improvements that have been implemented and documented at airport terminals of varying size with a goal of reducing energy costs by means of energy efficiency. Before implementation of any program or project, studies and decisions are required to determine the scope of the project, the cost of the project, funding sources, and potential payback or rebates. For the purposes of this report, these decisions are grouped under the term "planning."

This chapter discusses key planning and facility evaluation methods identified by respondents that are important to the successful design, funding, and implementation of energy efficiency practices.

ENERGY EFFICIENCY IN AIRPORT PLANNING

With energy as a significant percentage of yearly costs for most airports (usually 10% to 15% of the total operating budget), efficiency is identified as a high priority by respondents in current long-range plans. Based on survey results, many terminals are planning for energy improvements by including retrofits or upgrades in long-range plans whereas others work to save energy through energy audits and ongoing O&M plans. Literature sources also noted that it is important that strategic business plans include goals for efficient building operation as a part of asset management [Portland Energy Conservation, Inc. (PECI) 1999a, p. 3].

Plans can consider efficiency projects of all scales, costs, and paybacks to leverage investment. Although this report primarily addresses short payback, low-cost improvements, it is important to note that major, infrequent retrofit projects such as air handlers and boilers can also bring dramatic cost savings.

WAYS TO IDENTIFY ENERGY EFFICIENCY PROJECTS

O&M is a primary and cost-effective way airports can identify areas for energy efficiency improvements; however, commissioning and energy audits by local utilities also play a major role. A key to identifying where improvements are necessary or will be most effective is to collect and analyze data about airport systems.

Collect and Analyze Data with Audits and Meters

One of the most basic methods of gathering data about energy use is to perform an energy audit. Utility companies and energy service companies (ESCOs) offer many different types of audits. Most are no-to-low cost. Respondents suggested contacting the local utility company to determine the best audit method for a given facility. Airport staff or energy consultants can also perform audits. Audit types vary in scope and are typically dependent on facility type, size, and location. They can be done on existing and planned facilities.

Existing buildings can receive a re-commissioning or retro-commissioning audit to identify ways to save energy and reduce costs. Audit data also provide accountability to funding agencies and show money well spent or where design/construction fell short of promises by validating equipment performance. Nearly one half of survey respondents reported using audits for improvement identification.

Perform an Operations Assessment

In addition to gathering quantitative data, literature sources suggest that an O&M assessment be performed to identify optimization practices. These practices are potentially lower cost than retrofits identified by an audit (PECI 1999b, pp. 4–5).

> Box 1 Audit vs. Assessment
>
> Audits typically refer to the analysis of the energy used by existing equipment over a period of time, often resulting in technological solutions to save energy.
>
> Assessments focus on the evaluation of operations programs and procedures to identify low-cost improvements.

WEBLINK—CONSERVATION TIPS

Simple Steps to Conserve From the DOE

http://www1.eere.energy.gov/femp/services/energy_aware_oec.html

Review Energy Bills

Analysis of existing electrical, gas, and water meter data and billing reports can also identify anomalies and assist in

calculating project payback. By reviewing billing history, yearly escalation costs per unit of energy, which for some airports has exceeded 10% for natural gas, can be determined and applied to payback analysis, potentially shortening the payback term.

Recent literature relating to metering best practices identify two methods of utilizing meter data called "efficiency opportunity identification" and "operational opportunity identification" (Sullivan et al. 2007, pp. 7.7–7.8). Efficiency opportunity identification seeks to highlight variations in meter data for additional analysis, trending, and precision monitoring using portable means such as data loggers. Operational opportunity identification is described as "tuning" the building by comparing meter data with existing system parameters and settings to highlight failed, by-passed, disconnected, or defeated energy efficiency measures (Sullivan et al. 2007, pp. 7.7–7.8). See chapter four for additional discussion of audits and meters.

Start Early

Another tactic for identifying strategies is to begin thinking about efficiency early in any project. Integrating energy efficiency criteria into Pre-Design or Schematic Design phases of terminal projects through a design basis memorandum continues the commitments to efficiency established in long-range plans [Clean Airport Partnership, Inc. (CAP) 2003, p. 6]. In addition to specifically noting efficiency, the memorandum can reference commissioning and adequate funding and time for efficiency upgrades. When integrated into a project at the earliest phase, there is also less chance of resistance to improvements because many design criteria are just being established.

Reach for "Low Hanging Fruit"

This metaphor for seeking projects that are easy to achieve was seen by many respondents as a way to initiate cost-effective energy efficiency projects when resources are limited. One airport indicated that any improvement that qualifies for grants, rebates, or other assistance from the utility company is given highest priority. What is critical to this strategy is to select projects with "net incremental expenses repaid through energy savings (or rebates) and then quantifying the projected energy savings" such that the programs receive appropriate political attention and "aggressive but achievable conservation targets" are set (CAP 2003b, p. 8).

Leverage Commissioning Efforts

Interview comments by a consulting mechanical engineer indicated that when retrofit projects are commissioned, supporting equipment, ducting, or sensors are often found to be out of specification or in need of replacement.

Use Existing Standards to Guide Energy Efficient Design

A useful resource for determining energy use targets are the American Society of Heating, Refrigerating, and Air Condition Engineers (ASHRAE) and Illuminating Engineering Society standards such as ASHRA 55-2004, which in part establishes indoor temperature levels for comfort. Other national standards and quasi-public sustainability rating systems such as the U.S. Green Building Council (USGBC), Leadership Energy and Environmental Design (LEED®) program provides detailed high-performance building requirements and often strategies for achieving those requirements.

Box 2 Leadership Energy Environmental Design LEED®

Leadership in Energy and Environmental Design (LEED) is a point based system of evaluating, rating, and certifying sustainability in new and existing buildings. When a building is documented in compliance with the LEED guidelines it can be identified as LEED Certified.

The rating system and certification is administered by the U.S. Green Building Council (USGBC)—a non-profit corporation promoting sustainable building design.

Achieving certification for a building requires registration with the USGBC and documentation of sustainability strategies within a prescriptive point system. Many points concern energy efficiency and involve mechanical or electrical systems and occupant comfort. Handbooks and other resources for the LEED program include documented strategies for achieving points toward certification. LEED does not specifically cover airport terminals.

Because many smaller airport terminals function like small to mid-sized office buildings, strategies within LEED proposed for commercial construction offer an excellent resource for planning energy efficiency projects.

Specific practices cited within this report that contribute to LEED points include:

- On-site or off-site renewable energy
- System level metering

(U.S. Green Building Council 2008).

WEBLINK—USGBC LEED

More information about the LEED Program:

http://www.usgbc.org/LEED

STRATEGIES TO PLAN ENERGY EFFICIENCY PROJECTS

Small airports with limited budgets are often unable to dedicate funds to efficiency planning because of basic operational

needs. The following section documents resources or strategies that may assist in planning for projects.

Ensure Success—Incorporate Improvements into Projects and Plans

After identification of improvements or development of strategies, incorporation of those improvements into individual projects, O&M, airport budgets, and long-range plans will ensure improvements become reality. Some respondents noted the most success by including energy efficiency in the design of individual projects, whereas others incorporate energy efficiency into general or capital improvement budgets and long-range plans. Considering energy efficiency in long-range plans and general budgets will ensure consistent attention and funding and provide building data to justify additional improvements.

At a minimum, energy efficiency projects included within the budget can be implemented more successfully when projects can be broken down into phases, incremental steps, or by funding allocation for specific departments within the terminal/airport budget.

Energy Management Plan

In addition to typical plans and planning processes, a number of larger airports have dedicated energy management plans. A comprehensive energy management plan can describe energy efficiency measures to implement, promoting those measures with the highest rate of return and energy savings that will meet the facility's specific operational needs. Small airport operators might also consider dedicated management plans as a component of operational plans to be prepared for funding opportunities.

Test-Drive Strategies with Demonstration Projects

One unique planning concept noted by larger airport respondents, including Dallas/Fort Worth International Airport (DFW) and Minneapolis–St. Paul International Airport (MSP) is the use of demonstration projects. These tests often are initiated with vendor support and allow airports to evaluate new technologies before large-scale implementation and to secure other funding sources. This proofing is a challenge for small terminals, but can be used where opportunities are presented. Larger airport demonstration projects are a resource that can be shared with all airports.

Look to Other Terminals in Your Region for Practices

Comparing energy use at contemporary airport terminals with similar space programs, climates, and building areas may help to establish energy efficiency goals, especially if those airports have implemented successful energy efficiency programs (CAP 2003b).

Designate an Energy Advocate(s) on Project Teams

As a strategy to reduce the vulnerability of energy efficiency measures to "value engineering" within larger projects, interviewees suggested designating an energy advocate or panel to support and monitor energy efficiency aspects of the project through all phases of design and construction (CAP 2003b).

Pass it on—Generate Tenant Improvement Planning Standards

Renovation or tenant improvements within the airport terminal can be a way to reduce energy use and test practices for larger scale implementation. Providing proscriptive guidelines or standards for tenants allows the facility management to control and monitor improvements when O&M components are limited in airline leases or when tenants demand quick return on investments (CAP 2003a, p. 3). Examples range from simply specifying ENERGY STAR® compliant products as a part of the project to writing facility-specific (and usually more restrictive) energy codes or "LEED®" style standards. Customized standards developed with staff and consultant input can apply to many technical aspects of a project but may, at a minimum, apply to mechanical and electrical systems.

Future Proofing

An effective method of planning for energy efficiency noted by interviewees is to think ahead in anticipation of future technologies or changes in fuel or energy supply and integrate support systems into current projects. Known as "future-proofing," investments in the form of an additional conduit under pavements, heavier roof structure for photovoltaic (PV) panels, or larger mechanical rooms could reduce the cost of future retrofits or new projects (EPA and DOE n.d.a).

Seek Out Existing Documents and Programs

When planning for energy efficiency projects and programs, a wide variety of documents and resources can be consulted. Many smaller airports surveyed rely on other airport managers and consultants for information and data, whereas larger airports seek information from multiple sources including local and regional codes, sustainable building rating systems, consultants, and utility company programs.

Over the last decade, sustainability trends within commercial construction and real estate, as well as public and government construction, have led to greater accessibility to energy efficiency strategies for airport managers and consultants. Some programs, such as the EPA/DOE ENERGY STAR®

FIGURE 1 Existing energy efficiency programs. U.S. Department of Energy, ENERGY STAR Program logo with linkage phrase.

program, provide an energy performance rating system and energy management tools for achieving energy efficiency targets, whereas others such as LEED 2009 for Existing Buildings: O&M, include suggested strategies and technologies (for achieving points) related to energy efficiency (EPA and DOE n.d.a.; USGBC 2008) (see Figure 1).

WEBLINK—ENERGY STAR UPGRADE MANUAL

This manual outlines a process for developing a comprehensive energy-management strategy and an integrated approach to upgrading existing buildings:

http://www.energystar.gov/ia/business/EPA_BUM_Full.pdf

An additional resource developed concurrent with this report by the Sustainable Aviation Guidance Alliance is the Airport Sustainability Database ("Sustainable Aviation Guidance Alliance" 2009). This database seeks to be a comprehensive, searchable resource that identifies measures, including energy efficiency practices, to improve sustainability at airports.

Also concurrent with this report and developed by the Chicago Department of Aviation is the *Sustainable Airport Manual*. This update of a 2003 document was introduced in August 2009 and will include future chapters on planning and O&M (Chicago Department of Aviation 2009).

WEBLINK—ADDITIONAL PLANNING RESOURCES AIRPORT SUSTAINABILITY DATABASE (SAGA):

http://www.airportsustainability.org/database

WEBLINK—ADDITIONAL PLANNING RESOURCES SUSTAINABLE AIRPORT MANUAL:

http://www.airportsgoinggreen.org/SAM

FUNDING SOURCES FOR PLANNING

Airports large and small that have planned for energy efficiency most often have included funding for planning in the budget.

Dedicated Sustainability Budget

One major airport has broken out sustainability as a category within the budget, allowing critical review and accountability for energy efficiency and other environmentally focused projects. This reinforces direction from *ACRP Research Results Digest 2* to create an on-going energy conservation program with annual investment (Turner et al. 2007, p. 10).

Box 3 MSP Metropolitan Airports Commission MEC Program

Minneapolis/St. Paul International Airport (MSP) started focused planning for energy efficiency in 1998 with its MAC Energy Conservation Program, when $1 million was allocated through the Capital Improvement Program (CIP) for energy efficiency improvements. The budget for these improvements has grown to $2 million annually, and additional projects are continually identified for the program. Projects have ranged from chiller plant improvements and heat recovery from boiler stacks, to commissioning and building automation systems. The program continually looks at new technologies and new standards for potential future projects. The first 10 years of improvements (1998–2008) are expected to have fully paid for themselves by 2012.

Planning as a Part of Consultant Services

Other airports have innovated by requiring all mechanical and engineering consultants to consider and plan for energy efficiency as a part of basic services, thereby building in feasibility studies and planning into every project.

Utility Programs, Rebates, and Incentives

Additional planning resources have been found through local utility grant and rebate programs as well as federal grants. By focusing on projects eligible for grants or rebates, some larger airports are able to reduce the vulnerability of planning resources and programs within the budgetary process.

Utility programs help building owners and operators make informed efficiency decisions, implement energy efficiency strategies, and aid in reducing peak loads on the utility. Typical utility-directed programs are an energy audit, rebates, and capital incentives. Additional programs and rate arrange-

ments as well as other incentives for large energy users such as airports are also available (U.S. Department of the Interior 2006).

Rebate offerings vary greatly among utility companies and by location. Some improvements that may qualify include energy efficient chillers, lighting, lighting occupancy sensors, air conditioners, duct inspections/repair, solar window film, ceiling and wall insulation upgrades, motors, refrigeration equipment, heat recovery systems, and heat pump water heaters.

Interviewees stressed the importance of building a strong relationship with the local energy provider or utility as a key strategy for identifying energy efficiency programs.

Box 4 Retroactive Utility Rebates

Utility companies often require commercial customers to apply for rebates during the planning stages of larger projects. MSP has worked closely with its local electrical utility, Xcel Energy, to develop a Joint Efficiency Agreement Program that allows rebates to be applied for and received retroactively. The advantage of this program is that it allows projects to be fully developed before starting these discussions, and the final installation can be evaluated for rebate eligibility. It also allows smaller projects that may have been passed over to be reconsidered and not eliminated as a result of a procedural timeline.

ESCO Performance Contracts

Energy service companies provide a range of services related to improving energy efficiency and reducing maintenance costs for facilities. Services are performance-based, with compensation relating directly to energy saved. In addition to energy audits and other planning, ESCO's will also install, monitor, and finance retrofit projects with paybacks greater than five years.

An excellent initial resource for state, utility, and other incentive programs is the *Financial Incentives for Energy Efficiency* table compiled by the Database of State Incentives for Renewable and Efficiencies (see Figure 2).

WEBLINK—FINANCIAL INCENTIVES

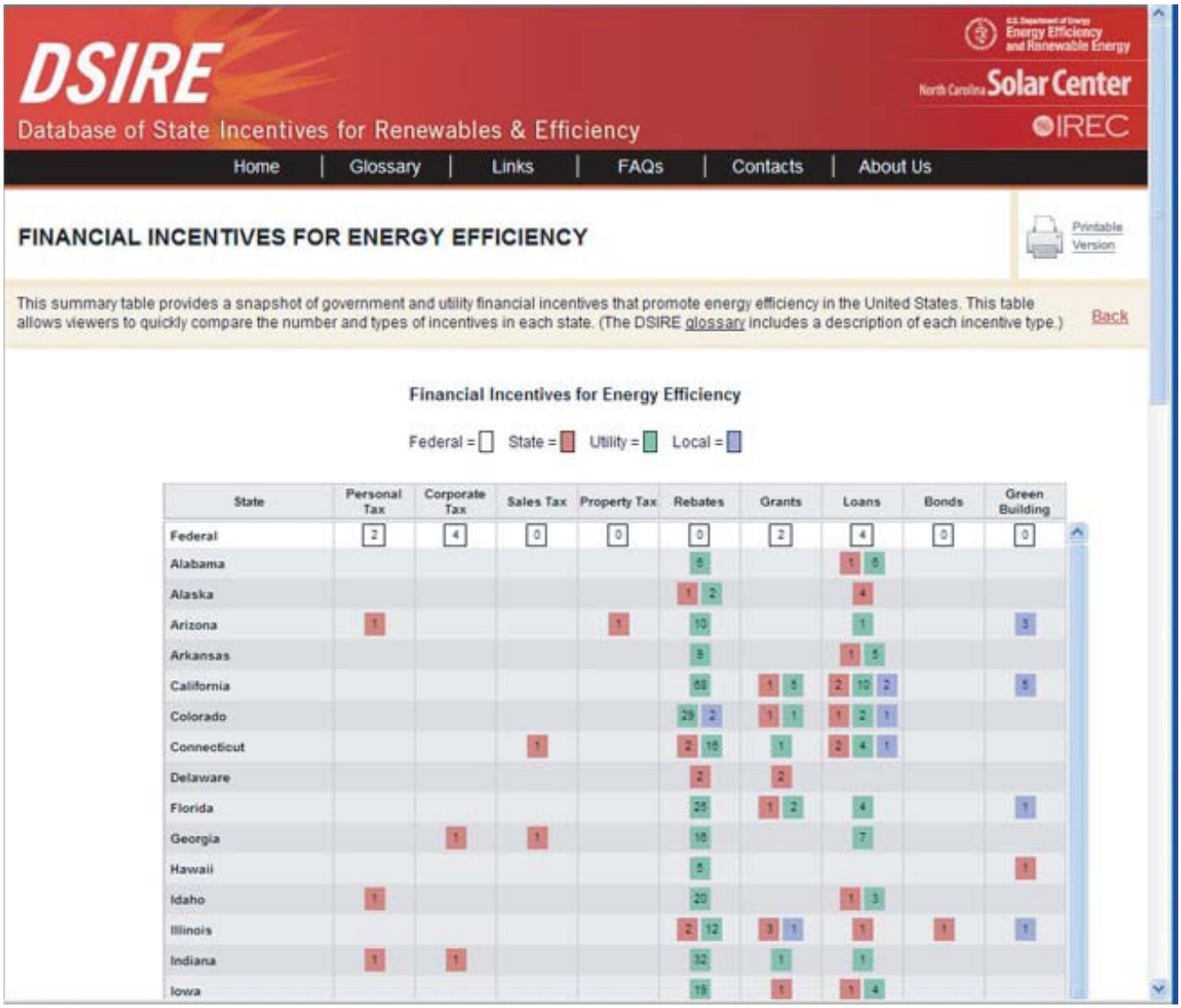
DSIRE—Financial Incentives for Energy Efficiency:

http://www.dsireusa.org/summarytables/finee.cfm.

PLANNING STRATEGIES SUMMARY

From data collected, the following strategies were discussed for planning energy efficiency practices.

- Consider energy efficiency in long-range plans.
- Consider energy efficiency every day in O&M.
- Create a separate sustainability plan.
- Include energy efficiency and feasibility studies in every project.
- Knowledge resources for planning energy efficiency projects include other airport managers, consultants, local ordinances, utility programs, and national standards.
- Primary funding resources for planning may be allocated in budgets but also can be found in utility grants and as a requirement of basic consultant services.
- Consider phased implementation or departmental prioritization to focus limited budgets.
- Use utility audits, O&M data, and commissioning to develop a list of energy efficiency projects.
- Search out utility programs for no-cost audits.
- Test improvement projects at a small scale to plan for larger scale implementation.
- Enforce efficiency with tenant and airport design standards.



State	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Bonds	Green Building
Federal	2	4	0	0	0	2	4	0	0
Alabama					6		1 6		
Alaska					1 2		4		
Arizona	1			1	10		1		3
Arkansas					9		1 5		
California					59	1 5	2 10 2		5
Colorado					29 2	1 1	1 2 1		
Connecticut			1		2 16	1	2 4 1		
Delaware					2	2			
Florida					25	1 2	4		1
Georgia		1	1		16		7		
Hawaii					5				1
Idaho	1				20		1 3		
Illinois					2 12	3 1	1	1	1
Indiana	1	1			32	1	1		
Iowa					19	1	1 4		

FIGURE 2 DSIRE website heading.

CHAPTER THREE

ENERGY EFFICIENCY PRACTICES: BACKGROUND AND UTILIZATION

The following three chapters of this report address examples of successful practices to increase airport energy efficiency. Sub-groupings of practices by operations category and system [envelope, heating, ventilation, and air conditioning (HVAC), lighting, etc.] will be described to further break down information and provide background. Discussion and explanation will elaborate on clear strategies and implementable practices identified during the survey and interview processes and literature review.

The terms improvement, strategy, practice, and action are used interchangeably throughout the text. All are meant to describe a physical or procedural process that has been documented to affect energy use at airport terminals.

CATEGORY AND TYPE OF PRACTICE

Practices fall into multiple categories, but are grouped by system to provide the most practical reference for facilities managers and consultants. Owing to limitations of the survey and unique conditions at each airport, projects may be retrofit for one facility and new at another.

Cost and payback data from the survey lacks precision and does not make a distinction between retrofit and new for each improvement; however, in literature sources it was noted that "[retrofit project] payback periods are generally much longer than the payback periods associated with instituting energy-related [operations and maintenance] and re-commissioning measures, which are often less than 2 years" (Turner et al. 2007, pp. 11–12).

METHODS FOR UTILIZING STRATEGIES

Although any strategy could be planned, studied, and implemented as an independent project, most will take place as a component of a larger investment. When major equipment upgrades and other longer payback (10+ years) improvements are undertaken it may be worthwhile to group them with short payback projects such as lighting retrofits or optimization programs "to help offset initial costs and improve the return on investment" (Turner et al. 2007, p. 13).

As supported by one interview respondent and stated in previous ACRP research, "enhanced re-commissioning would also be a part of any retrofit project and prioritized like any other individual retrofit measure when calculating the overall project payback period" (Turner et al. 2007, p. 13). Some strategies, such as lighting upgrades, may already be part of ongoing maintenance programs. Others may take significant planning before implementation.

The *age of the terminal facility* as noted by interviewees has significant bearing on where improvements make sense. Younger facilities may consider pursuing operations related to improvements, whereas older terminals would benefit from equipment upgrades or automation. Airport operators can use this list of practices to initiate discussion with staff and consultants, and determine which strategies are most applicable to their facility.

PAYBACK, COST, AND PERCENTAGE OF IMPROVEMENT

Simple payback was found to be a common method of determining feasibility for energy efficiency projects in initial literature reviews and was used as a metric within the airports survey. Practices are identified in terms of simple payback time in years and implementation cost relative to total budget. Survey data from small airports were prioritized when available.

In an effort to make the survey useful to the consultants and easy to complete by respondents without excessive research or time, project cost was requested relative to overall budget. Cost can be defined as total project cost and not cost per square foot. Although the precision of this metric may vary as the result of wide-ranging airport sizes and diversity of respondents, it was believed to represent a good qualitative assessment of the project by persons with direct and holistic knowledge of airport operations at their facility. As such, it is useful information in conjunction with payback. Cost information is based on energy rates for 2009 at respondent airport locations.

Payback periods are dependent on several factors (from Turner et al. 2007, p. 13):

- Energy rates
- Hours of operation

- Climate conditions
- Relative efficiency of equipment and/or controls being installed or replaced
- Design condition requirements
- Interdependency of savings when more than one (energy efficiency improvement) is installed.

OUTLINE STRUCTURE

Improvements are organized within the following structure:

Level 1: **SYSTEM**
Level 2: **Subsystem/Type/Operation**
Level 3: *Energy Efficiency Strategy/Action/Improvement/Practice*

CHAPTER FOUR

ENERGY EFFICIENCY PRACTICES: MANAGEMENT AND OPERATIONS

This chapter of the report will discuss practices for improving energy efficiency at airports as they relate to energy management, including automation and controls, systematic assessment, special programs and operational arrangements, and personnel and human factors.

At an in-depth level the automation discussion will highlight ideas regarding upgrade and optimization of building automation systems, techniques for calibrating and adjusting interior temperatures, and specific controls retrofits supported by automation. Following automation, improvements to O&M practices in relation to both new and retrofit projects will be articulated into practices addressing methods of systematic assessment including audits, O&M assessment, and options for commissioning. Topics related to special or unique programs and arrangements used by airports to guide, implement, and monitor energy efficiency projects will highlight project criteria, temporary settings, and O&M service contracts. Finally, human factors influencing energy efficiency will be discussed. These include targeted training programs for personnel and tenants, communications strategies for creating a "conservation culture," and psychological effects of certain retrofit practices.

Box 5 Practice Metrics Key

Following the title of each practice in chapters four and five, icons representing cost and payback are listed. Icon values are as follows:

Low Cost = $
Med Cost = $$
High Cost = $$$
0–2 year Payback = 🕘
2–5 year Payback = 🕘🕘
5–10 year Payback = 🕘🕘🕘
10+ year Payback = 🕘🕘🕘🕘
Example: $$| 🕘🕘🕘 = this improvement has a Medium Cost and 5- to 10-year payback.

Notes:
- For a limited number of practices, payback and cost information was not determined.
- Practices with a payback of more than 10 years are beyond the scope of this report and are mentioned for information purposes only.
- Where percentages are noted, the value given represents a yearly reduction in energy or operations costs for that system or process.

AUTOMATION AND CONTROLS

Computer controls, sensors, and whole-building automation are used extensively by respondents to monitor and reduce energy consumption and provide data to support future energy efficiency projects.

Building Automation Systems

A building automation system (BAS) or Energy Management Control System (EMCS), identified as a best practice by numerous sources, "allow the building HVAC and lighting systems to react automatically to the operating environment, adjust to meet load conditions, and help schedule or identify equipment needing maintenance or adjustment" (Turner et al. 2007, p. 10). Small airports often have some form of BAS providing minimum function such as "fire safety, security, and indoor air quality" (Turner et al. 2007, p. 3).

BAS Thermal Environment Calibration **$**| 🕘

A variety of indoor thermal environments exist within airport terminals, ranging from gate-hold to baggage handling. Maintaining comfortable conditions for occupants with different metabolic rates and clothing levels who are departing to and arriving from different climates or continually entering and exiting the building can be a challenge for BAS and airport operators. Standards established by ASHRAE specify conditions of the indoor environment for occupant comfort. ASHRAE 55-2004 can be used for new construction and retrofit programs to establish parameters for proposed HVAC systems and to evaluate existing thermal environments. Although not prescriptively listing thermostatic settings for buildings, the standard provides guidance for determining acceptable conditions (Olesen and Brager 2004).

A majority of survey respondents that indicated energy savings were attained by adjustment of space temperature settings described variously as "temperature adjustments and equipment shut down during non-peak hours"; "programmable thermostats"; "increase cooling temperature ranges"; "space energy settings of 74 to 78 degrees summer, 70 to 74 degrees winter" (noted by Phoenix Sky Harbor International—PHX); and the utilization of "occupied/unoccupied temperature set locks."

Other sources noted that the best strategy for implementing temperature settings was to reset thermostats incrementally

"one degree per week" to gradually transition spaces and occupants and reduce complaints by tenants (CAP 2004, p. 10).

Cost/Payback/Savings: In a heating condition "each degree of thermostat offset [higher] saves approximately 2% of cooling energy [per year]" (Lynch and O'Rourke 2008, p. 26).

BAS Sensor Optimization **$**| ◴ - ◴◴

An often-quoted concept relating to mathematics and computer science termed "garbage in-garbage out" might be kept in mind when managing building automation systems. Without accurate sensor calibration, BAS can return inaccurate data, potentially wasting energy, disrupting occupant comfort, and causing unnecessary wear or replacement of system components (Turner et al. 2007, p. 10).

Optimization for HVAC and BAS can offset aging mechanical equipment and related sensors, and detect temporary repair or other emergency measures that have become "permanent" fixes, ultimately saving energy resources (Turner et al. 2007, p. 10).

Cost/Payback/Savings: Payback for optimization of BAS/EMCS sensors has been documented at 1 to 4 years (Turner et al. 2007, p. 14).

Box 6 Open Source Automation

Currently being implemented at MSP, Open Architecture Building Automation (OABA) is an extensive program that replaces building controls and facility monitoring systems with new, nonproprietary systems, allowing the maintenance and operations staff to competitively bid work that was previously sole sourced by the respective vendors. While implementing OABA, extensive testing was undertaken to improve equipment efficiency and update building controls, and system improvements have been included as hundreds of pieces of equipment have been modified for the new system. When fully implemented this system is projected to deliver $150,000 in savings over the first 3 years by allowing improved controls and maintenance of equipment. This is one of the first open architecture building control systems in the world.

BAS Upgrade **$$**| ◴◴◴

BAS can reduce off-line time for crucial equipment by detecting fluctuations in performance or degrading components and alerting O&M staff earlier, potentially reducing unnecessary energy costs and more expensive repairs. Conversely, when poorly calibrated or incorrectly installed, BAS can increase energy consumption (Turner et al. 2007, p. 10).

A number of respondents and interviewees noted implementing various levels of building automation as a key aspect of energy savings, with many commenting that without automation, energy efficiency improvements would not have been identified in the first place. These systems vary in size and scope of control and were identified by a number of names or acronyms including "Intelligent Monitoring and Control System" (IMACS)—"Open Architecture Building Automation" (OABA), as well as "automated building control system" (ABCS), "Direct Digital Control (DDC)," and "computer controlled terminal systems" or "automatic timed controls."

For many facilities, including at those interviewed, automation has become part of all building-related capital improvement projects and/or been an ongoing (yearly) retrofit for distinct systems or terminal areas (concourses). A larger airport noted that "automation of building systems is standard in new facilities," whereas another noted an upgrade strategy of "replacing building control system in multi-year phases" was improving efficiency.

As noted in other ACRP research, "an effective BAS requires well-trained personnel, ongoing maintenance, calibration, and well developed control schemes" (Turner et al. 2007, p. 12).

In addition to terminal improvements for automation, airports noted that other automation efforts have increased efficiency including "networking ancillary building HVAC systems" and "extensive automation of district energy plant and distribution system."

Cost/Payback/Savings: Owing to the scale of airports and extensive variety in automation systems, costs for new systems can vary. Payback for upgrades to BAS/EMCS has been documented at 6 to 10 years (Turner et al. 2007, p. 14). If nondigital/pneumatic systems are being replaced, additional savings can be found in the decommissioning of those systems (Turner et al. 2007, p. 14).

BAS Improvements Related to Lighting See Lighting in chapter five.

BAS Improvements Related to Continuous Data Acquisition See Continuous Commissioning in the Operations and Maintenance section of this chapter.

Box 7 Pneumatic Control Retrofit

Los Angeles International Airport (LAX) Tom Bradley International Terminal, a 25-year old, 1 million ft^2 facility is undergoing extensive renovations and expansion. These improvements include the replacement of 19 roof-mounted air handlers, variable-air-volume (VAV) distribution boxes, and an outdated pneumatic control system. New direct digital controls coupled with other practices are predicted to reduce energy use by 10% annually.

(Illia 2008; Seidenman and Spanovich 2008: Mawson 2009;)

Motor Controls

In conjunction with building automation and systems monitoring, electric motors within many existing air-handling, pumping, and conveyance equipment can be outfitted with computer controls or variable frequency drives (VFDs) that sense real-time load or demand and automatically adjust to optimal efficiency (Turner et al. 2007, p. 13). These controls provide more precise feedback to operations staff, allowing adjustment and fine-tuning of settings to accommodate airport schedules and occupancy. Multiple respondents indicated utilization of motor controls on a variety of equipment. Smaller airports used VFD fans, whereas larger airports also used VFD pumps and cooling tower fans.

Fans—Variable Speed Drives **$| ◷ - ◷◷**

Application or replacement of VFD controls to fans through a BAS was identified as an energy saving action by a majority of airports surveyed. Respondents indicated payback durations of between 0 and 5 years and low cost, which correlates with other findings by Turner of 3 to 7 years for simple payback (Turner et al. 2007, p. 14).

Pumps—Variable Speed Drives **$ - $$| ◷◷**

Motor controls for pumps were used by various sized airports and were noted to have a payback time of 2 to 5 years and low to medium cost (see Figure 3).

FIGURE 3 Motor controls. Variable frequency drives for condenser water pumps save energy at MSP Airport. (*Courtesy:* Michaud Cooley, Erickson Engineers.)

Fans—Cooling Tower **$ - $$| ◷◷**

Retrofit of cooling tower fans with variable drive was identified by larger airports as an energy efficiency strategy with paybacks ranging from 2 to 5 years and low to medium cost.

OPERATIONS AND MAINTENANCE

Respondent airports and literature sources noted that evaluation of on-going engineering programs and system evaluations such as energy audits and commissioning can significantly improve energy efficiency in airport terminals. Earlier studies noted that all airports should prioritize the "development a comprehensive energy-related O&M program with clearly defined goals and benefits" as a way of improving energy efficiency (Turner et al. 2007, p. 10). Further, it was stated that it was important that these programs "set aggressive goals and secure funding and senior management support [and maintain] implement and monitor benchmarked results" (Turner et al. 2007, p. 10).

It is the opinion of some experts that "while effective . . . capital upgrades [like equipment replacement] are not always the most cost-effective solution" and "that low-cost/no-cost O&M measures . . . should be the first energy savings measure considered" (Turner et al. 2007, p. 10). Reasons given for this assertion consider the low cost of O&M measures, ability of in-house staff to implement improvements, and immediate payback of O&M actions (Turner et al. 2007, p. 10). In addition, these improvements "rarely require the design time, bid preparation, evaluation, and response compared to capital projects that can take up to a year to implement" (Sullivan et al. 2004, p. 2.3).

This report generally agrees with this assertion, but cautions that for many small airports, limited staff resources and outside facility management contracts may increase implementation cost and payback time.

Respondents suggest that small airports identify a party to manage the implementation of specific energy-related O&M practices. This position at a small airport may be best performed by a specialist with previous experience in performing commissioning at the facility.

Systematic Evaluation

Influenced by "record high energy prices, an increased number of building re-commissioning agents, and the increased awareness of airport executives and the public of the direct link between energy and the environment," evaluation and

maintenance of existing systems will continue to be an accessible, effective, and valuable method of improving energy efficiency (Turner et al. 2007, p. 5).

More than half of the survey respondents have initiated energy audits, assessments, or other intensive energy studies. Building commissioning, periodic re-commissioning, or on-going commissioning for existing facilities through building automation was noted as providing additional savings in energy costs by a number of respondents. Phoenix Sky Harbor International Airport noted that its first commissioning attempt was recently undertaken.

Energy Audits **$** | 🕘

Energy audits can take on various forms and scopes, but all types focus on evaluation of the energy used by existing equipment over a period of time. Traditional audits result in technological solutions to save energy. Energy bills are often reviewed for inconsistency with monitoring equipment and errors as well as trends in an effort to identify efficiency opportunities.

As part of an equipment replacement process (investment grade) energy audits are often a financing requirement that serves to provide assurance that the "investment is financially sound" (PECI 1999b, pp. 4–5).

Cost/Payback/Savings: Energy audits are often performed for free by the local utility.

WEBLINK—Energy Efficiency Handbooks

These handbooks by the California Energy Commission include comparisons of different types of energy audits and information on identifying energy efficiency projects.

http://www.energy.ca.gov/reports/efficiency_handbooks/

O&M Assessment **$ - $$** | 🕘 - 🕘🕘

An O&M assessment seeks to reduce operating costs and improve efficiency by recommending "low-cost changes in O&M practices that can improve building operation" (PECI 1999b, pp. 4–5). They can be performed before or concurrent with energy audits and may aid in reducing the payback time for capital improvements identified in the energy audit because of low-cost operations improvements (PECI 1999b, pp. 4–5). By utilizing assessment in preparation for an audit, their complementary nature may be exploited to identify additional or more precise areas of investigation in the audit.

Cost/Payback/Savings: Costs for O&M assessments are typically equivalent or sometimes more than energy audits; however, implementation costs are small relative to large capital improvements (PECI 1999b, pp. 4–5). PECI reports that "managers can consider most O&M assessments outside of typical corporate hurdle rates, because the risk of not realizing savings is so low" (PECI 1999b, pp. 4–5).

Energy Assessment **$$** | 🕘 - 🕘🕘

Energy assessments offer a combined evaluation of equipment and operations and are often performed by external experts. As such, these reports that identify "potentially beneficial equipment upgrades, needed equipment repairs, and beneficial changes in operating procedures" can represent the most objective opinion of what is needed to reduce costs and therefore be very useful in support of energy efficiency programs (Turner et al. 2007, p. 11). Turner indicated that comprehensive assessments be undertaken every five years.

Re-Commissioning and Optimization **$** | 🕘

Re-commissioning and optimization for existing buildings or systems will return those systems to design specifications while accommodating facility or tenant operating requirements. These actions can apply to single systems in a "Value Re-Commissioning" approach or include comprehensive building evaluation to support extensive retrofit/remodeling (Sullivan et al. 2004, p. 7.2). Because of its temporal nature, re-commissioning is most effective for buildings or tenant spaces lacking consistent maintenance. A change in tenant or use within a space offers an opportunity to re-commission systems serving that space.

Specific optimization actions cited by respondents included "chiller controller reprogramming through a BCS/EMS [energy management system] system"; "monitoring of chiller plants to avoid peak demand charges"; and shut down of hot water boilers in the summer months." Other optimization actions noted by Sullivan et al. include:

- Adjust reset and set-back temperatures and temperature settings—Settings are often adjusted over time based on personal preferences, to compensate for inadequate system operation, or to achieve energy savings. In addition, sensors require periodic recalibration.
- Staging/sequencing of boilers, chillers, and air handling units—Equipment should be operated in the most efficient combination of chillers, boilers, and fans at varying load conditions.
- Adjust and repair dampers and economizers—Malfunctioning or poorly tuned dampers (including seals, actuators, and linkages) and economizers result in (1) increased supply air fan energy in the closed position or require additional air heating and cooling when open too much, (2) undesired building operating conditions owing to lack of outside air, and (3) premature equipment degradation and replacement.
- Modify control strategies for standard hours of operation—Motors, pumps, fans, and air handlers often operate on a 24/7 schedule even though not required by either the building tenants or the building operating plan.
- Eliminate simultaneous heating and cooling—Heating and cooling systems for the same space can compete against each other owing to improper setpoints.
- Air and water distribution balancing and adjustments—Systems require rebalancing due to drift and changing building/workspace mission and/or tenant requirements.
- Verify controls and control sequencing including enabling and re-enabling automatic controls for setpoints, weekends, and holidays. Verify that overrides are released (Sullivan et al. 2004).

These optimization strategies can often return both energy efficiency savings and O&M improvements if they are performed

by staff and will raise awareness of energy savings potential. However, consultation with a skilled agent may be necessary for complex improvements. By targeting specific systems or components of a system through value re-commissioning data "can be used to demonstrate benefits of larger, more aggressive existing building commissioning program" (Sullivan et al. 2004, p. 7.2).

Cost/Payback/Savings: Optimization efforts typically have a payback of less than two years (Sullivan et al. 2004). Other benefits of optimization for mechanical systems can include longer equipment life and a reduced chance of equipment failure.

Box 8 Programmatic Assessment

Programmatic assessments are especially useful when planning for renovation or retrofit. Evaluate occupancy patterns and space uses to determine if original design and mechanical/lighting specifications are still in place or if changes to space mean changes to system settings.

"Have occupancy patterns or space layouts changed? Are HVAC and lighting still zoned to efficiently serve the spaces?"

(PECI 1999c, p. 4)

Basic Commissioning **$ - $$$** | ◷ - ◷◷

Basic commissioning, as a part of O&M best practices, is cited multiple times in the literature (Liu 2002; Sullivan et al. 2004; Commonwealth of Pennsylvania n.d.) as a primary method for improving performance and efficiency of building systems.

Basic commissioning for a new or retrofit system or building ensures that equipment is installed and operating properly. When taking possession of a building or system that has undergone commissioning, owners gain assurance that equipment is operating within design parameters and specifications (Sullivan et al. 2004, p. 7.2). In addition, the training implemented for staff as well as data and documentation collected will ensure optimal operations and support future re-commissioning (see Figure 4).

It is suggested that commissioning be initiated early in the design process to achieve the greatest benefit (Potter et al. 2002).

Specific projects that warrant commissioning as identified by the PECI include:

- All projects that include controls
- Pneumatic equipment
- Integrated systems
- HVAC-related plant equipment and air distribution systems

FIGURE 4 Data gathering for commissioning. A variety of tools and sensors are used to measure airflow speed and pressure, component and air temperature, electrical power and voltage. From Top Left—Counter Clockwise: Fluke 87 Multimeter: Used for general measurement of electrical voltage, current, and frequency. Dranetz PowerXplorer: Used to measure and data log very small fluctuations of electrical voltage, current, and frequency. Primarily used when testing data center electrical systems. Shortridge Instruments-AIRDATA Multimeter—ADM-860: Used to measure airflow, velocity, pressure, and temperature. Vaisala Temperature/Humidity Meter: Used to measure data log temperature and humidity. (Center) Raytek Infrared temperature Gun: Used to measure surface temperatures. (Image and descriptions courtesy Michaud Cooley Erickson Engineers.)

- Lighting sweeps or day-lighting controls
- Energy management systems and control strategies
- Variable speed drives in motors
- Ventilation air and control
- Building pressurization control
- Refrigeration improvements
- Capacity controls for heating and cooling plant equipment (PECI 1998, p. 55).

Cost/Payback/Savings: Costs and payback time will vary owing to scale and scope of the commissioning of project.

WEBLINK—Commissioning Resources

Portland Energy Conservation, Inc. provides an in depth list of on-line commissioning resources:

http://www.peci.org/cx_resources.html

Continuous Commissioning™ **$$$** | ◷ - ◷◷

Continuous Commissioning™ describes a commissioning practice that is integrated into the day-to-day O&M program at a facility. Data compilation, calibration, and other activities are performed on a regular (often daily) basis. This contrasts to other commissioning events, which are distinct and

temporal in nature. The approach was developed by the Energy Sciences Laboratory at Texas A&M University and is made possible by the integration of utility systems and some building systems to allow centralized monitoring and data acquisition (Liu 2002).

The Continuous Commissioning™ process or any similar ongoing monitoring program allows staff to discover problems within systems immediately and for those problems to be addressed as they occur. This rapid assessment serves to maintain optimal efficiency for systems and increase preventive maintenance to increase the life of the system. Further, because data are constant, energy savings are continuous and ongoing.

Specific actions and operating strategy modifications implemented through the Continuous Commissioning™ process at DFW included equipment staging, temperature and pressure reset, and modified operating schedules.

Cost/Payback/Savings: Because Continuous Commissioning™ is dependent on both BAS and advanced metering technologies, as well as requiring significant staff support, it is mentioned for information and not as a low-cost strategy. Energy efficiency benefits resulting from continuous commissioning were reported to be significant with more than $3 million in measured and verified energy savings over a 5-year period by DFW. In studies of this assessment method outside the DFW facility, it was reported that following implementation, "the average measured utility savings are about 20%, with simple paybacks often in less than two years" (Liu 2002, p. 1.1). A 2006 DOE study indicates savings of up to 45% yearly energy costs from an "ongoing commissioning program" (Sullivan et al 2007, p. 8.3).

Box 9 An Important Part of Continuous Commissioning: Baseline Models

Once the commissioning scope has been defined and a preliminary audit is performed, it is necessary to document existing conditions or create what is known as a performance baseline model in order to determine energy savings following commissioning.

Baseline models can be developed data gathered over variable periods of time including "short term measured data obtained from data loggers or the EMCS system" and "Long-term hourly or 15-minute whole-building energy data, such as whole-building electricity, cooling and heating consumption, and/or utility bills for electricity, gas and/or chilled or hot water" (Liu 2002, p. 1.6).

Collecting short-term data for a baseline is usually more economical than collecting long-term data; however, "long-term data often produce additional savings, making them the preferred data type." (Liu 2002, p. 1.7)

Special Programs and Operational Arrangements

A number of airports noted the creation of special programs to guide, implement, and monitor energy efficiency projects. These and other operational strategies that are infrequent or one-of-a-kind as identified by respondents are noted in this section.

Maintenance Agreements **NO-$** | ◷

One aspect of operations that can assist in achieving reductions in energy costs at small airport terminals concerns agents hired to perform periodic service at their cost on mechanical and electrical equipment and facilities. O&M contracts for low-cost and quick payback measures can include requirements and incentives for energy savings (Sullivan et al. 2004, p. 3.6; PECI 1999a, p. 13). Quite often these incentives will cause contractors to utilize re-commissioning measures to secure incentives.

Tampa International Airport (TPA) and DFW noted using maintenance agreements to aid in the implementation of energy efficiency practices. Data did not indicate if these agreements were with energy service companies.

Cost/Payback/Savings: This action was identified as a no-cost improvement with immediate payback.

Preventive Maintenance Programs **NO-$** | ◷

Survey respondents and literature reported the implementation of various programs within operations to improve energy efficiency and reduce costs.

- Document O&M procedures—The documentation of "O&M procedures in a centralized manual reduces dependence on individual specialized knowledge or expertise regarding airport systems" (Turner et al. 2007, p. 10).
- Whole system maintenance such as light fixture cleaning and bulk re-lamping or window cleaning.
- Seasonal review of O&M strategies and schedules to fit climatic variations (PECI 1999c, p. 4).

Cost/Payback/Savings: Because these programs are already part of the operations budget, no additional cost is incurred. Payback information varies, however, as noted elsewhere, operational improvements initiated by staff often have a payback of less than 1 year.

Box 10 Energy Service Company Contract

Energy service companies (ESCOs) provide performance based services with compensation relating directly to energy saved. See chapter two for more information on ESCOs.

Temporary Settings/Mothballing **$|** 🕘

When airport facilities are underused or unoccupied, plans can be in place to shut down or mothball nonessential systems to reduce energy use. One survey respondent reported that "due to flight reductions we have closed off one concourse to reduce heating, cooling and lighting." Others noted "semi-mothballing unoccupied or under-occupied facilities"; and "baggage and security system temporary shutdown when activity is reduced." By shutting down boilers during the summer months, Montgomery Regional Airport (MGM), Montgomery, Alabama, indicated that natural gas expenses dropped 50%.

Literature described setup and setback strategies for building temperature settings during nighttime operations that sets high and low limits for cooling and heating systems to reduce HVAC cycling when spaces are unoccupied (PECI 1999c, p. 23).

Costs/Payback/Savings: The cost of shut down or mothballing spaces can be quite low if BAS control is used. Payback for nighttime temperature settings is often less than one year (PECI 1999c p. 23).

Energy Efficiency Specific Project Criteria **$ - $$**

Many survey respondents indicated that design and construction standards at their facility include aspects of energy efficiency. Others noted the used of payback or return on investment (ROI) criteria for any efficiency-oriented improvements.

One benefit of implementing nationally recognized standards is that staff or consultant time is saved by not having to develop standards; however, national scale programs have limitations when applied to unique climatic conditions such as temperature extremes or programmatic requirements of airport terminals and often have rigorous documentation requirements. Standards are referenced in chapter two.

Cost/Payback/Savings: If standards exist, no cost. If national rating systems are referenced, again costs can be low.

Airport Sustainability Programs **$ - $$|** 🕘 **-** 🕘🕘

Fostering an operations culture that supports energy efficiency will garner long-term commitment to improvements from staff and airport users alike.

In 2007, MSP instituted a comprehensive, airport-wide program to promote sustainability and stewardship of airport resources. This program notes in its vision statement that "being good stewards means operating and developing our airports in ways that meet the needs of the present without compromising the ability of future generations to meet their own needs" (Metropolitan Airports Commission 2009).

Box 11 MSP Metropolitan Airports Commission STAR Program

At Minneapolis/Saint Paul International Airport (MSP), the Metropolitan Airports Commission (MAC) has implemented a comprehensive sustainability program entitled Stewards of Tomorrows Airport Resources (STAR) (see Figure 5). Energy efficiency components of the program, noted as "MAC ACTION" have included the following:

- Installed ground power and pre-conditioned air at gates
- Implemented annual energy conservation projects
- Installed energy-efficient lighting
- Implemented day-lighting window design
- Implemented automatic lighting controls
- Utilized automatic HVAC settings and controls
- Upgraded both hot and chilled water central plants.

(Metropolitan Airports Commission 2009)

Interviewees noted that this comprehensive program, which addresses aspects of energy conservation and renewable energy as well as eight other categories has been essential in promoting a "culture of sustainability" begun by the MAC Energy Conservation Program in 1998.

FIGURE 5 Culture of sustainability. An informational document for Minneapolis/St. Paul International Airport sustainability program: Stewards of Tomorrows Airport Resources. (*Courtesy:* MSP Metropolitan Airports Commission.)

Personnel/Human Factors

A major aspect of making effective changes to operations practices for energy cost reduction involves personnel and their attitudes toward energy efficiency. As noted earlier in the special programs section, creating a "culture of sustainability" within the airport operations department and across airport and tenant staff will ensure that programs and practices are implemented and followed. Indeed, DFW noted that after multiple presentations about the airports' energy conservation program to tenants and staff ideas for improving energy efficiency are now being generated outside of operations.

The Hawthorne Effect **NO-$**| 🕘

The Hawthorne Effect references an early 20th century study of workers at the Hawthorne Plant of the Western Electric Company in Cicero, Illinois. Findings from that study indicated that the behavior of workers may be altered in a positive direction when they are aware of the study.

As energy efficiency improvements are initiated (especially ones that increase monitoring of energy use such as submetering) small gains in efficiency can be expected when personnel are aware of the improvement, owing to the Hawthorne Effect (Clark 1999).

Training **$**

A number of airports have implemented "energy awareness" training programs for staff and tenants to raise awareness about energy efficiency measures. A limited number have mandated staff work practices to reduce energy use. Although mandated practices may result in some savings, literature recommends that management actively "track and measure the success of energy-efficiency strategies [and] share energy accounting info with O&M staff to help identify problems and track successful strategies" (PECI 1999a, p. 7).

In addition to awareness training, operations training for O&M staff and day-to-day users of airport equipment, from simple thermostats to energy management control systems, is crucial to the successful utilization of those energy management tools. An example given in a PECI report notes the importance of returning controls to original settings.

> Because many parties, perhaps even tenants, often have access to lighting and HVAC controls, schedule changes to meet special needs or unusual conditions may not get returned to their original settings. Over time, these schedules become further and further removed from matching actual needs (PECI 1999c, p. 21).

Communications **$**| 🕘

For the Hawthorne Effect to take place, information about energy cost-reduction practices must be distributed to personnel and stakeholders. This communication can take many forms and use multiple channels within airport operations and public-use areas. It can also be as simple as a sticker on a light switch suggesting that lights be switched off when exiting the room (CAP 2004).

Information sharing in the form of a monthly newsletter was used at one large airport interviewed. This communication strategy has proven to raise awareness about energy efficiency issues and provide savings through vigilance on the part of O&M staff. At another airport, energy efficiency program staff has made numerous presentations to stakeholder groups including tenants and are seeing gradual but positive changes in attitudes towards energy efficiency.

Department of the Interior strategies for raising awareness suggest "providing mandatory and voluntary training opportunities on smart energy practices [and] holding annual energy fairs before seasonal changes to provide additional information for employees about how to manage energy use in the work place and in their homes" (DOI 2006).

Additional communications methods include periodic notifications about turning off lights (see Figure 6), printers, and computers; designating space for energy efficiency information within staff common areas; or drafting monthly or quarterly informational e-mails about planning, improvements, energy data, or other areas of operations that can affect energy efficiency.

Communicating about energy efficiency with tenants is also important and, as noted in the next chapter with regard to metering data, can be effective in reducing adversarial relationships. One interviewee noted the positive effects brought about by communicating to tenants that some airport fees had not increased for five years because of energy efficiency projects.

Box 12 Communications: Cultivating a Culture of Conservation

Communication is an important tool on multiple levels: Intranets, newsletters, and other means of disseminating information among airport staff, airlines, and other tenants are very useful in educating the people that inhabit the airport on a daily basis about the benefits of energy efficiency programs, and the impact that their individual actions can have on energy efficiency and other environmental programs. Some airports reported success expanding communication efforts into related programs, including employee carpooling at DFW, and alternative work schedules at Tampa International Airport (TPA), where some employees work four 10-hour days, decreasing their commuting costs by 20%.

FIGURE 6 Communication with building occupants. Light switch stickers used to encourage energy conservation at a student dormitory. (*Courtesy:* Office of Sustainability—Temple University.)

Chapter Summary

From the data collected, the following practices were discussed for reducing energy cost and improving energy efficiency within building management and operations at airport terminal buildings (see Table 1).

- Upgrade and optimize building automation systems to ensure performance within specifications
  - Calibrate and adjust interior temperatures for optimal occupant, staff, and tenant comfort
  - Utilize building automation systems with motor controls for heating, cooling, and conveyance systems.
- Identify improvements to O&M practices by using systematic assessment for both new and retrofit projects
  - Methods of systematic assessment include energy audits and O&M assessment
  - Multiple forms of commissioning can be used depending on project type and scope.
- A variety of programs and arrangements are used by airports to guide, implement, and monitor energy efficiency
  - Highlight energy efficiency within new project criteria
  - Utilize temporary settings for underused systems and spaces
  - Include energy efficiency requirements within O&M service contracts.
- Human factors can affect the success of energy efficiency programs
  - Provide targeted training programs for personnel and tenants
  - Identify communications strategies for creating a "conservation culture"
  - Psychological effects can provide small savings.

TABLE 1
ENERGY EFFICIENCY PRACTICES—BUILDING MANAGEMENT AND OPERATIONS

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[1]					PAYBACK[2,3]					%[4] Energy Savings
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown	
AUTOMATION / CONTROLS													
Automation improves monitoring and and management of building systems.	BUILDING AUTOMATIONS SYSTEMS												
	Allow the building HVAC and lighting systems to react automatically to the operating environment, adjust to meet load conditions, and help schedule or identify equipment needing maintenance or adjustment.	**BAS Thermal Environment Calibration**		■				■					2%
		BAS Sensor Optimization		■				■	■				
		BAS Upgrade			■					■			
	MOTOR CONTROLS												
	Heating and cooling systems are outfitted with computer controls or variable frequency drives (VFDs) that sense real-time load or demand and automatically adjust to optimal efficiency.	**Fans - Variable Speed Drives**		■				■	■				
		Pumps - Variable Speed Drives		■	■				■				
		Fans - Cooling Tower		■	■				■				
OPERATIONS AND MAINTENANCE													
O & M should be the first airport area studied for energy cost savings.	SYSTEMATIC EVALUATION												
	The evaluation and maintenance of existing systems is an accessible and effective method of improving energy efficiency.	**Energy Audits**		■				■					
		O & M Assessment		■	■			■	■				
		Energy Assessment			■			■	■				
		Re-Commissioning / Optimization		■				■					5-15%
		Basic Commissioning		■	■	■		■	■				
		Continuous Commissioning				■		■	■				
	SPECIAL PROGRAMS & OPERATIONAL												
	Use special programs to guide, implement and monitor energy efficiency projects.	**Maintenance Agreements**	■					■					
		Preventive Maintenance Programs						■					
		Temporary Settings / Mothballing		■				■					
		Energy Efficiency Specific Project Criteria		■	■								
		Airport Wide Energy Sustainability Programs		■	■			■	■				
	PERSONNEL / HUMAN FACTORS												
	Personnel and their awareness and attitudes toward energy efficiency projects are an important part of implementation.	**The Hawthorne Effect**	■					■					
		Training		■									
		Communications		■				■					

Notes:

1. Payback—time indicated refers to years required for improvement to return cost savings equivalent to project costs.
2. Cost information is based on energy rates for 2009 at respondent airport locations.
3. Cost can be defined as total project cost and not cost per square foot.
4. Percentage—value given represents a yearly reduction in energy or operations costs for that system or process.

CHAPTER FIVE

ENERGY EFFICIENCY PRACTICES: ENERGY USE AND SYSTEMS

This chapter of the report will discuss practices for improving energy efficiency at airports as they relate to energy use, including potential impacts on and ideas about energy sources, mechanical systems, lighting, and other energy loads.

At an in-depth level the source discussion will highlight practices regarding both carbon-based and renewable energy, techniques for documenting and managing energy use with metering systems, and practices for improving energy rate structure and minimizing peak loads with utility providers.

Following sources, improvements to mechanical systems in relation to both new and retrofit projects will be broken down into tactics addressing major heating and heat recovery components and strategies affecting cooling components.

Topics related to lighting will address lamp and fixture retrofit and replacement options as well as extensive discussion of sensor and control improvements used by respondent airports. Finally, additional major equipment energy loads that are somewhat unique to airports will be discussed. These include changes to visual information displays and efficiency techniques for conveyance systems.

SOURCES

Natural gas was the predominant fuel type at most airports surveyed. This fuel is vulnerable to cost increases such as all carbon-based sources—sometimes to dramatic effect at a large consumer such as an airport. This was dramatically demonstrated in 2000 at Seattle–Tacoma International Airport (Sea–Tac) when natural gas prices increased 8,000% and the annual energy bill climbed from $5 million dollars to more than $17 million in one year (CAP 2004). Future energy sources that will reduce energy costs are largely based on solar power, although in some parts of the country where biomass is available cogeneration plants may also serve to meet airport energy needs.

For the near future, carbon-based, nonrenewable fuels will continue to be used at airports to generate electricity, hot water, and steam. As resources are depleted and greater carbon controls put in place, airport terminals and other large commercial buildings will be affected by rising energy costs.

Multiple Fuel Sources

As mentioned previously, fuel costs will fluctuate based on national and global events, and in extreme cases large energy users can be dramatically impacted when tied to a single source of fuel. Having the option to utilize additional fuel sources protects the airport from dramatic fluctuations.

By agreement with their primary fuel provider, one survey respondent is able to switch to more economical boiler fuel during transition seasons, resulting in a substantially lower energy rate and the elimination of winter use charges. Another airport noted that jet fuel, a readily available energy source at airports, could be used by facilities on a limited basis for peak load shedding.

Renewable Energy

As an update to findings in *ACRP Research Results Digest 2,* this synthesis found limited utilization of on-site renewable power at the airports surveyed.

Solar Photovoltaic **$ - $$$** | 🕘 - 🕘🕘🕘🕘

Large-scale solar PV systems have found limited applicability at airports seeking low-cost energy efficiency improvements with a few exceptions noted here. The technology is still largely unable to compete with nonrenewable power in most regions. Because of rapidly changing technology, materials, and installation costs, solar PV technology is mentioned both as a viable, low-cost improvement here and as a future technology in chapter eight.

Two airport respondents noted the installation of grid-tied, on-site PV arrays. Both airports, Phoenix Sky Harbor International (PHX) and Fresno Yosemite International (FAT), are located in regions with higher solar resources as identified by the DOE.

Cost/Payback/Savings: Payback time for solar PV systems at airport terminals depends largely on where the airport is located and what rebates or incentives are provided by local utilities, and state and federal governments. An average payback time of greater than ten years is expected; however, FAT noted a 1-year payback on its recently installed system. This 2.4-mW project was estimated to supply 42% of electrical

Box 13 Fresno Yosemite International, California, Photovoltaic Field One Year Later

The initial cost of installing photovoltaic (PV) or wind generation systems, although less costly than in the past, is still prohibitively expensive, especially for medium-sized and smaller airports with limited budgets. One notable exception to this situation is Fresno Yosemite International, where a combination of incentives from the State Public Utilities Commission and a third-party contractor were utilized to install a 2.4 mW PV field (see Figures 7 and 8).

Selected through a Request for Proposal process, the third-party contractor designed and constructed as well as owns and operates the installation on airport property. The agreement provides the operator use of airport land and the airport with electricity at a fixed rate for 20 years (at slightly higher than the current market rate).

After one year of operations, the PV field actually provides 58% of the airports power, exceeding projections. The fixed electrical rate is now expected to save the airport more than $19 million in utility charges over the 20-year period. One of the keys to these savings is that the peak production of the PV field coincides with the airports peak energy use, substantially reducing its peak demand. This installation also has the ability to sell excess power to the grid.

FIGURE 7 Solar photovoltaic array in Fresno, California. The 2.4 mW field shown in the lower right provides more than 50% of the electrical power required for the airport terminal. (*Courtesy:* Fresno–Yosemite International Airport.)

FIGURE 8 Photovoltaic panels and supports at Fresno Yosemite International. (*Courtesy:* Fresno–Yosemite International Airport.)

needs and save the facility $13 million in energy costs over 20 years (Schwartz 2009).

Metering Energy Use

Energy use data are extremely valuable to airports seeking to reduce energy costs. Improvements in energy use metering in recent years have made it possible to obtain precision data. With these data, airport energy managers and operations staff are able to verify utility bills, benchmark systems, and determine where improvements are needed to save money. Metering technologies allow airport operators to initiate best management practices, monitor trends in energy use, and improve building operations (Sullivan et al. 2007, p. 2.1).

In the future, if federal, state, or local mandates demand greater accounting of energy use, advance metering will allow airports to comply with legislation such as the *Energy Policy Act of 2005* ("H.R. 6–109th Congress: Energy Policy Act of 2005," 2005; Sullivan et al. 2007, p. 2.2), which updated federal building performance standards and required all new federal facilities to implement advanced metering.

Benchmarking with Meters

Utilizing energy use data from meters to develop building-wide energy benchmarks is essential to assessing performance, setting goals, and evaluating change. Benchmarking supports retrofit or upgrade projects, because it identifies how and where energy is used and also what factors contribute to energy use (EPA and DOW 2009).

WEBLINK—Benchmarking Resources

Energy Star Portfolio Manager: On-line tools to track and assess energy consumption:

www.energystar.gov/benchmark

General Metering Impacts

As noted in the last chapter, by communicating intentions to provide more precise metering and goals for energy efficiency to personnel behaviors may be adjusted because new monitoring is in place. The Hawthorne Effect alone may provide savings of up to 2% (Sullivan et al. 2007, p. 8.3). Typically, the use of meter data "will result in energy cost savings that can be used to justify the cost to purchase, install, and operate the metering system" (Sullivan et al. 2007, p. 2.5).

Interviewees noted that data provided by metering has allowed airport managers to more effectively negotiate lease rates and tenant fees. Data also provide concrete information to communicate to staff to gain support for sustainability programs at the airport.

The potential cost savings from additional metering depends on a number of factors, primarily the unit cost of energy and the ability to implement projects derived from the meter data. By using meter data for optimization or "building tune-up" or in support of a continuous commissioning process, observed savings of 5% to 15% of yearly energy costs may be possible (Sullivan et al. 2007, p. 8.3). Savings of greater than 15% may only be realized if significant opportunities for energy efficiency exist as a result of insufficient operations or worse, neglect (Sullivan et al. 2007, p. 8.3).

Service Meter Data Baseline **$**| 🕘

Determining an energy use baseline for a system or building is useful to begin the energy efficiency and cost reduction process. With a baseline, the energy savings of an improvement or retrofit project can be accurately estimated and precisely confirmed. In addition, any optimization or recommissioning process should begin with an accurate energy use baseline for that system or piece of equipment (Turner et al. 2007, p. 11).

Most airport respondents noted that electrical power usage was currently measured with one meter. Although not ideal for tracking energy use and identifying energy projects, because individual users cannot be identified, basic assessments, audits, and baseline information can be performed and established using meter data and energy bills. In comparison to advanced or smart meters, most meters at airports would be classified as "standard meters," which can be defined as "electromechanical or solid state meters that cumulatively measure, record, and store aggregated usage data that are periodically retrieved for use in customer billing or energy management" (Sullivan et al. 2007, p. 2.1).

Cost/Payback/Savings: As with many other O&M practices, a payback period of less than 2 years is typical when establishing an energy baseline.

Advanced Meters **$**| 🕘 *(with utility support)*

An advanced metering system gathers energy use data on a defined schedule as well as on-demand, enabling real-time monitoring of electrical use, time-based electrical rates, and continuous commissioning. The system can, at a minimum, provide data daily to support operations and other energy management functions (Sullivan et al., 2007, p. 2.1). Only one survey respondent reported the use of advanced metering systems. Their "real-time meters" were provided by the utility.

Cost/Payback/Savings: "Metering system costs vary widely for a number of reasons: equipment specifications and capabilities, existing infrastructure, site-specific design conditions, local cost factors, etc." (Turner et al. 2007, p. 8.1). EPAact Section 1252 regarding smart metering technology may require utilities to provide smart meters to their customers in the event that the utility can offer time-base rates (Sullivan et al. 2007, p. 2.3). See the next section on Energy Rates for rate adjustment information.

Electronic Sub-Metering **$$**| 🕘

As a complement to standard meters, electronic sub-metering is endorsed as a way to cost-effectively determine energy use by multiple users, systems or tenants, add a finer grain to energy data, and prepare for emerging energy guidelines (Millstein 2008). Sub-meters provide a fair and time saving method of processing bills that can reduce conflict between management and tenants. They also send price signals, alerting wasteful tenants and encouraging conservation (Turner et al. 2007, p. 6). Finally, and perhaps most important to the focus of this report, sub-meters allow accurate tracking of energy use and monitoring of energy efficiency improvements.

Sub-meters saw limited utilization among survey respondents. St. Louis International Airport indicated that sub-meters are used in terminal areas to monitor tenant energy use, whereas another airport indicated a limited capability to sub-meter owing to unknown reasons.

Cost/Payback/Savings: Research noted that by using meters to provide "bill allocation only—savings of 21/2% to 5% can be attained, largely owing to improved occupant awareness" (Sullivan et al. 2007, p. 8.3).

Energy Rates

By understanding utility rate structures, incentive programs for reducing loads and penalties, or peak demand charges, airport terminals are better prepared to manage energy use and reduce costs.

Energy rates continue to rise for airports in most parts of the country—in some cases with dramatic monthly increases (CAP 2004). When billing history is reviewed, yearly rate

escalation costs per unit of energy can be calculated and incorporated into payback analysis, potentially shortening the payback term.

Rate Adjustment with Advanced or Sub-Meters **$**
(when meters are provided by utility)

Utility companies around the country offer a number of rate-based programs aimed at improving the reliability of the electrical grid. Quite often advanced metering systems are required to enroll in these programs, which may be provided by the utility. By utilizing advanced metering data, airport terminals can have a greater understanding of their unique load characteristics and a more knowledgeable position when negotiating rate-based programs (Sullivan et al. 2007, p. 7.6–7.7). Most rate-based programs work to incentivize off-peak use of electricity and reduce peak load demand. Specific programs include time-of-use pricing, real-time pricing, and load aggregation.

About half of the survey respondents noted a negotiated rate structure with their local utilities, including rates for bulk energy users.

Cost/Payback/Savings: Low cost when meters are provided by the utility.

Peak Load Shedding 🕘

A method of energy management that can reduce the impact of peak demand rate increases is peak load shedding. The building automation system and meters are used to shed electrical loads or "turn-off" noncritical systems during peak demand periods (CAP 2003a, p. 13; DOI 2006). Turner noted that this method of cost savings "works best at facilities with large summer cooling loads, and it requires a dedicated O&M staff and a favorable utility electric rate structure to be economically viable" (Turner et al. 2007).

Airports surveyed noted penalties in the form of peak-hour demand charges associated with peak loads.

Cost/Payback/Savings: Paybacks of less than one year were reported by The College of New Jersey when metering and management were used to shed peak loads by cycling HVAC equipment in multiple buildings (New Jersey Higher Education Partnership for Sustainability n.d.).

MECHANICAL HEATING, VENTILATION, AND AIR CONDITIONING

HVAC can consume greater than 40% of electrical energy at airports, with most of that being used by air conditioning systems. With the exception of small systems such as domestic hot water, HVAC systems consume nearly all the natural gas used at an airport. Within these two areas of high consumption and energy cost come many of the opportunities for significant energy efficiency savings through retrofit projects.

Heating—Hydronic

Solar Thermal **$$** | 🕘🕘

Solar thermal systems consist of roof-mounted panels through which water or a glycol/water mixture passes to gain thermal energy. This heated fluid is then pumped through a high-efficiency heat exchanger, which transfers energy to potable water to be used for space heating or domestic hot water. Although costs have dropped, solar thermal heating systems and collectors have achieved significant increases in efficiency and reliability over the last 30 years (DOE 2003).

The use of solar thermal systems for hydronic heating (space or hot water) was largely absent at all airports surveyed, with only one respondent, DFW, indicating in the affirmative. Although a more proven technology than PV, solar thermal technology may only have limited applications for small airports. The best application of this technology may be for domestic hot water or snow-melt systems and not for primary heating. Solar thermal can also be used to supplement boiler systems (DOE 2008).

Cost/Payback/Savings: DFW indicated a 2- to 5-year payback and medium level cost.

Central Boiler Upgrades **$ - $$$** | 🕘 - 🕘🕘🕘🕘

Although boilers and associated components of a hydronic heating system vary owing to the size and complexity of an airport terminal, it is generally assumed that replacement of major components in a heating/cooling system will be a significant cost to any airport terminal. For older facilities, boilers are often oversized and inefficient. Replacement brings greater efficiency, multiple fuel options, and reduced maintenance costs (Turner et al. 2007, p. 13). Additional strategies may include replacing one boiler with multiple units and the addition of direct digital controls to increase boiler efficiency (DOE 2008).

Of airports surveyed, boiler replacement was the primary heating system improvement. Survey results varied depending on the size of the airport and type of system, with an overall greater percentage of respondents indicating some type of boiler replacement to improve efficiency.

Cost/Payback/Savings: Airports surveyed reported that boiler-related energy efficiency improvements provided a 0- to 5-year payback and could be achieved for a range of costs—from low to high. Literature noted payback ranges for specific retrofit options including "oversized boiler replace-

ment"—6 to 8 years; "high efficiency boiler replacement"—8 to 12 years (Turner et al. 2007, p. 14).

Energy Recovery Systems

Heat recovery units increase heating and cooling efficiency by capturing or "recovering" energy from exhaust air or chiller water that would otherwise be lost. Systems transfer heat from warmer air to cooler air in heating or cooling modes, reducing these loads depending on the season. Air-to-air heat exchangers, classified as "heat recovery," remove only heat, whereas others, classified as "energy recovery," remove both heat and water vapor from the air stream (Turner et al. 2007, p. 13; DOE 2009b). Various materials are used in the air-to-air heat exchanger, with some requiring greater maintenance than others. Systems typically achieve transfer efficiencies of 70% to 80% (DOE 2009b; Commonwealth of Pennsylvania n.d., p. 43).

Plate and Frame (Fluid) Heat Exchangers **$$**| 🕘

High-efficiency plate and frame heat changers transfer energy over a greater surface area than traditional fluid heat exchangers, greatly increasing the speed of the process. This type of heat exchanger is used as a component of the cooling system chiller.

Plate and frame heat exchangers installed at Seattle Tacoma International Airport (Sea–Tac) in 2004 were notable because of their projected savings of more than $1,000 per day and installation by engineering staff in "the equivalent of a weekend." Payback based on projections was less than one year (CAP 2004).

Air-to-Air Heat Exchangers **$$**| 🕘🕘 - 🕘🕘🕘

Air-to-air systems use a film or plate over which the air passes to transfer energy between supply and exhaust airstreams. Systems are modular and adaptable for a range of air stream capacities and should be considered where design conditions require continuous exhaust and make-up air (Commonwealth of Pennsylvania n.d., p. 43). Systems work best in extreme climates where temperatures outside are significantly different from indoor temperatures. In mild climates, the energy consumed by continuous powered exhaust may offset any gains found using heat recovery technology. Also, in cold climates, systems are typically equipped with frost control measures (DOE 2009b).

Survey respondents noted limited implementation of heat recovery systems. Primarily used by larger facilities, the technology holds promise for many small airports, and may be considered as a component of mechanical retrofit.

Cost/Payback/Savings: Medium level implementation costs were noted by survey respondents. Literature noted a payback of 8 to 10 years (Turner et al. 2007, p. 14).

Box 14 Building Ventilation Systems

Exhaust ventilation systems are common in almost every commercial and institutional building, and therefore one of the most common sources of wasted energy. Two airports had specific examples of the often unseen but significant impact of inefficient exhaust ventilation systems.

One airport reported that the restroom exhaust was controlled with the restroom lights, which were historically left on continuously. The air handling equipment of the HVAC system was also controlled by these lights, to provide make-up air for the exhaust fans. By replacing the lighting controls with occupancy sensors, savings were created in all three systems: lighting, exhaust, and HVAC.

Another airport reported that their best efforts at promoting energy efficiency were often circumvented by human actions: Tenant employees of concessionaires would open their doors to the terminal when their kitchen became hot, effectively adding a commercial kitchen to the terminal's air conditioning load as the commercial exhaust hood would draw in cool air from the terminal. By implementing independent make-up air for the kitchen exhaust, the airport is able keep these functional ventilation zones separate and operate the terminal more efficiently.

Cooling

Primary energy efficiency improvements in the area of cooling by airports surveyed consisted of replacement or upgrades to central chillers and rooftop air-handlers and/or split systems. Life expectancy for mechanical systems serving commercial buildings is widely variable—ranging from as little as 10 years to as long as 50 years in the case of ground-source heat pumps (DOE 2008). When replacement occurs as a result of age, it is very likely that it will result in energy savings simply because of improvements to the technology.

Central Chiller **$$**| 🕘🕘 - 🕘🕘🕘

Much like boilers, chillers and other components of the cooling system are often oversized or have become oversized owing to reduced cooling loads generated by lighting retrofits. Replacement with properly sized units that more closely match cooling loads will bring reduced energy costs. Conversely, if chiller size is deemed inadequate, improvements reducing cooling loads may be less than the cost of additional chillers. A limited number of airport respondents noted some form of chiller replacement, with one noting a full replacement for a terminal (see Figure 9).

Cost/Payback/Savings: The 2- to 5-year payback for the one large airport (PHX) indicated that a full replacement

FIGURE 9 Central chiller replacement. Chiller and condenser upgrades at MSP Lindbergh Terminal. (*Courtesy:* Michaud Cooley Erickson Engineers.)

was somewhat less than the 8 to 20 years reported in literature sources (Turner et al. 2007, p. 14), most likely owing to the size of the facility. Costs were noted as medium level as might be expected by a major retrofit project.

Packaged Heating and Cooling

Rooftop Air-Handlers with Gas-Fired Furnaces or Split Systems $$| ◷◷

Rooftop air-handlers, commonly referred to as roof-top-units or RTUs, are a low-cost HVAC system used in commercial buildings including small airport terminals. The simplest system packages the major components of heating, cooling, and ventilation within one unit, located on the roof. Improvements within this type of system largely come from increased combustion efficiencies. For split systems, where air-handlers and condensers are located on rooftops and variable-air-volume (VAV) boxes or other distribution is located within the conditioned space, efficiency comes from the ability to deliver conditioned air only where it is needed. Split systems also allow individual control, improving thermal comfort of occupants (DOE 2008).

Limited use of packaged systems was noted by survey respondents at large airports; however, smaller airports did note retrofits.

Cost/Payback/Savings: A payback of 2 to 5 years was consistently noted but costs were mixed, most owing to the variety of systems.

Packaged Air Conditioners $$| ◷◷

Packaged or individual air conditioning units are typically used to cool special areas or rooms within airport terminals including communications and data closets and electrical and elevator equipment rooms. The investigators experience with more than 30 years of aviation architecture tells us that at most airports data and communications rooms continue to increase in size and cooling demand owing to more advanced building automation and communications. Survey respondents noted limited energy efficiency efforts applied to this type of system; however, as with other cooling components, older systems will benefit from greater efficiency when upgraded.

Costs/Payback/Cost: Limited responses noted a payback of 2 to 5 years and medium cost to implement this improvement.

Economizer ◷◷◷

Economizers are a modification to outside air intakes that allow them to utilize outside air when temperatures meet specifications. Within climate zones that have cold winters, such as the Upper Midwest, Northeast, and other areas where mandated by building code, the economizer function reduces energy required to meet cooling loads and can account for significant reductions to cooling related energy cost at certain times of year (CAP 2003a, p. 17; Turner et al. 2007, p. 13; Commonwealth of Pennsylvania n.d., p. 42).

Although most commercial buildings can benefit from economizers, the unique conditions at airports require additional controls as a result of fuel and exhaust odors. Interviewees from two airport terminals noted the use of economizers with air quality sensors.

Cost/Payback/Savings: "Economizer equipment upgrades have a payback of 4 to 8 years" (Turner et al. 2007, p. 14).

LIGHTING

Lighting accounts for approximately 25% of electrical use in most commercial buildings (Benya et al. 2003, pp. 3–4). At airports, this can increase to 40%. After O&M improvements, lighting holds the greatest potential for energy savings at small airport terminals. Retrofits related to lighting systems can have significant impact on other, potentially more costly infrastructure upgrades such as boilers and ventilation equipment owing to the reduction in cooling loads provided by more efficient fluorescent fixtures.

Lighting upgrades free up power for other systems or facility expansion. In one case cited by a respondent, lighting improvements, coupled with other energy efficiency projects, eliminated the need to construct a new energy plant. Lighting upgrades also have the potential to improve productivity and occupant comfort by improving light quality and levels, improve controllability by turning lights off or balancing levels

with daylight, and reduce maintenance costs by tracking and increasing lamp life.

Lamp and Fixture Retrofit

Survey respondents and many other sources cited lamp and fixture retrofits as low-cost energy efficiency improvements that return significant savings. It may also be noted that lighting improvements are one of the most noticeable ways to save energy, which, along with visual display upgrades, may elicit positive feedback from airport occupants and be used to promote a sustainable image for the facility.

WEBLINK—Demonstration and Evaluation of Lighting Technologies and Applications (DELTA) Program—Resources for Energy Efficient Lighting Solutions—Commercial Publications:

http://www.lrc.rpi.edu/programs/DELTA/publications/commercial.asp

Upgrade to Fluorescent Screw-in Bulbs $|

A strategy used by a majority of respondents is to upgrade screw-in incandescent fixtures to compact fluorescent lamps (CFL), which use up to 75% less energy and last significantly longer (EPA and DOE n.d.b). The cost of CFL fixtures has dropped "significantly" in recent years (Turner et al. 2007, p. 12), making this upgrade even more affordable. Maintenance savings may also be found owing to reduced replacement frequency.

Cost/Payback/Savings: This low-cost strategy has a typical payback of less than 2 years.

Fluorescent Fixture Upgrade $|

One of the most cost-effective lighting upgrades that can achieve a "20 to 25 percent" electric power reduction is to replace existing T-12 magnetic ballast fixtures with new T-8 or T-5 lamps with electronic ballasts. A large majority of respondents reinforced the popularity of this strategy and generally supported research data regarding payback.

Cost/Payback/Savings: Survey respondents indicated a payback of 0 to 5 years and low implementation cost.

Controls and Sensors

Estimates of 15% to 45% reductions in yearly energy savings can be found when lighting controls are properly "specified, installed, commissioned and operated" (Benya et al. 2003, pp. 8–11). Savings depends on the habits of previous occupants and existing lighting management strategies. One interviewee noted that adjusting sensors to shut lights off just ten seconds earlier each day can add up to measurable savings over the course of a year.

Box 15 Re-lamping Highlight

Although often noted as a high-efficiency lamp, fluorescents are limited in lighting output relative to other lamps, specifically high-intensity-discharge or HID. Areas where conversion from fluorescent to HID may be appropriate include exterior security lighting on terminals and within parking structures attached to terminals.

An interviewee at Lambert–St. Louis International Airport noted that in a "a major parking structure renovation we replaced the fluorescent fixtures with HID resulting in better lighting at 40% less energy cost." He added further that "the renovations would have required all the fixtures and most of the conduit [be] removed anyway and [the] new installed cost of one HID fixture versus four new fluorescent fixtures was insignificant and made up in labor savings in conduit and wiring to one fixture instead of four with the ability for better circuiting."

MSP noted that existing circuiting placed significant limitations on the scope of improvements and the ability of the project to meet payback criteria.

Timer Lighting Control $|

Controlling the time when light fixtures are on or off is one of the most basic methods of limiting energy consumed and saving operating costs. Clock timers or daylight timers triggered by a photocell for interior or exterior lights has found broad use by respondents as a low-cost energy saving measure (see Figure 10).

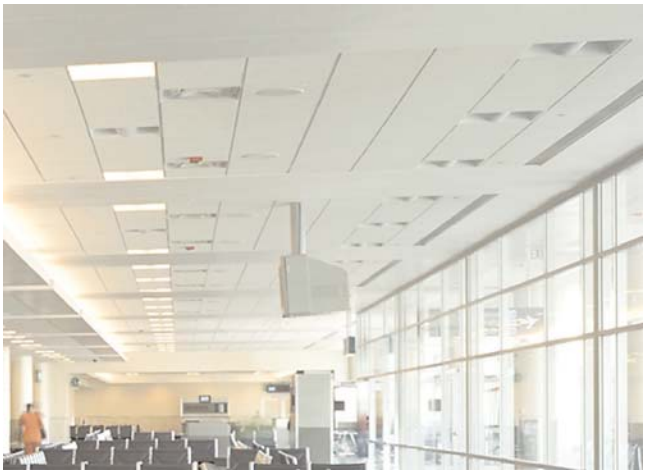


FIGURE 10 Lighting controls at MSP Humphrey Terminal. Controls monitor daylight and switch off fixtures adjacent to windows when not needed.

Costs/Payback/Savings: Survey respondents indicated a payback of 0 to 5 years for lighting timers.

Bi-Level Switching **$**

A method of lighting control that provides flexibility for use and occupancy within a space is bi-level switching. In most cases, wiring allows multiple lamps to be controlled within a single fixture to accommodate up to four distinct lighting levels (Benya et al. 2003). Typical applications for bi-level switching would be staff work areas or conference rooms.

This strategy saw limited implementation by survey respondents. It holds potential for greater control if intelligent lighting controls are implemented in the future.

Cost/Payback/Savings: Bi-level switching has been noted as low cost by respondents.

Multi-level Switching/Daylight Harvesting with Photocells **$| 🕘 - 🕘🕘**

A subset of lighting controls tied to daylight photocell sensors called multi-level switching was noted as an energy efficiency strategy by a number of airports surveyed. With multi-level switching, lighting levels in areas such as gate-hold, ticketing, and other areas with typically extensive windows are reduced by switching off lamps within fixtures, balancing artificial light with daylight, and maintaining even lighting with all fixtures on. This type of improvement requires more sophisticated controls and has greater applicability where BAS exists (Benya et al. 2003, pp. 8–15).

One airport indicated that airline tenants expressed concern about implementing a daylight controlled system, but supported the project once even light levels could be maintained through multi-level switching.

Costs/Payback/Savings: Among most survey respondents, a payback period of 0 to 5 years and low cost was indicated.

WEBLINK—National Lighting Product Information Program (NLPIP)—Technical and application information about sensors and other energy efficient technology:

http://www.lrc.rpi.edu/programs/NLPIP/technologies.asp

Occupancy Sensors **$ - $$| 🕘 - 🕘🕘**

Occupancy sensors are a specific lighting control that detects movement or sound to determine when a space is occupied and shuts off fixtures after a specific period of time if no occupancy is detected. They can be utilized in a variety of spaces including toilets, storage closets, stairwells, hallways, and other areas with limited use or unpredictable use patterns (Benya et al. 2003, pp. 8–19; DOI 2008). Occupancy sensors may extend the life of fluorescent lamps, thereby increasing the re-lamping interval and providing extra savings (Benya et al. 2003, pp. 8–15).

One interviewee commented that initial settings for occupancy sensors at a major airport were to shut off after 15 minutes of inactivity during nighttime hours. This had little effect because of cleaning crews and security sweeps. Only when reset down to two minutes were the sensors able to function as intended.

Cost/Payback/Savings: Survey respondents indicated 0- to 5-year payback and low cost. Literature cited a range of savings that vary depending on the area size, type of lighting, and occupancy pattern; the most current literature from the DOE notes claims of up to 75%; however, "the CA Energy Commission estimates that typical savings range from 35–45%" (DOI 2008). Mounting sensors to existing light switch boxes can be challenging in large areas or where extensive renovations have obscured sensor mounting to movement.

Central Automated Lighting Control **$ - $$| 🕘 - 🕘🕘🕘**

Another type of lighting control system involves centralized control of all lighting fixtures within the terminal. By using central control, areas of activity can be monitored and tracked, and neglected or problem areas identified. In addition, some central controls can track total hours that lamps have been in service, supplying operations staff with useful information with which to schedule re-lamping programs (Benya et al. 2003, pp. 8–15). One settings strategy noted by PECI was to program lighting controls to periodically turn off all lights within a certain area of the building during the overnight hours (PECI 1999c, p. 25). Lighting reduction during non-peak hours and utilization of central lighting control was a common practice among survey respondents.

Cost/Payback/Savings: Literature noted that less than 1-year payback can be expected through energy savings and reduced staff monitoring; however, some respondents noted payback of 5 to 10 years and low to medium cost.

ELECTRICAL LOADS

In addition to lighting, visual displays and conveyance systems are prominent consumers of energy within airport terminals. The addition of modern baggage management and security screening systems continues to increase energy costs at many

respondent terminals. Implementing controls that allow reductions in energy consumption based on loads or temporary shut down during off hours can mitigate impacts of expanded systems.

Visual Information Displays

The communication of flight and baggage information at airports is done primarily by electronic displays. These displays are often in large composite assemblies in custom cabinets. At many airports surveyed, cathode ray tube (CRT) displays were once common but have largely been replaced by energy efficient liquid crystal displays (LCDs) or wide-screen plasma display technology. In addition to passenger displays, energy efficiency upgrades can also be made to staff computer displays and entertainment and advertising systems.

Display Shutdown **$**

Turning off information displays and staff computer monitors when not in use can reduce energy use and has been identified as a low to no-cost strategy for airports.

Displays on staff and tenant workstations can be shut down or placed in sleep mode during off hours. Visual information displays for baggage systems can be automatically or manually shut down between flights, depending on the level of automation available. Manual shutdown is typical at most airports surveyed. BAS can be utilized for flight information display system and baggage displays.

Display Retrofit **$| 🕘 - 🕘🕘🕘🕘**

Retrofit of CRT and other outdated visual displays used for flight information display system, baggage, parking, and advertising with energy efficient display technology has been done at a majority of surveyed airports. Respondents noted the retrofit of CRT displays with flat-screen, LCD (see Figure 11), light emitting diode (LED), or plasma displays.

Benefits of flat screen displays include lower power consumption, lower weight, reduced heat, and better image contrast (EPA and DOE n.d.c). LCD displays have been found to use up to 50% less energy than CRT and generate less heat, thereby reducing cooling loads (EPA and DOE n.d.c.).

There are also claims that improved flight information displays can "lessen fuel consumption and costs associated with delayed flight departures" by facilitating more rapid gate information updates on screens that are easier to read, thereby getting passengers to the gate and onto the aircraft faster (Ackerman 2009, p. 26).

Cost/Payback/Savings: Survey respondents reported a payback of 0 to 2 years and low cost. Literature sources found longer payback of 11 to 13 years on replacement of CRT with LCD using 2005 costs (Ng 2005). LCD costs continue to drop; therefore, a shorter payback may be expected.

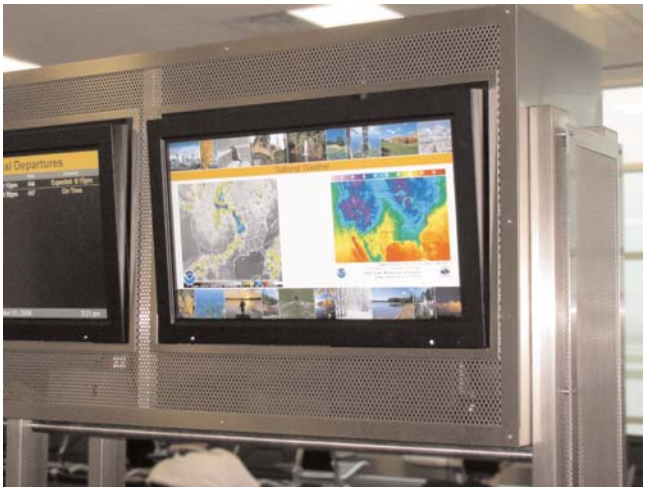


FIGURE 11 Information display. Flight information display retrofit with LCD monitor.

Conveyance Systems: Controls for Baggage Conveyors, Escalators, and Moving Walks

A number of practices that increase energy efficiency were noted by interviewees for conveyance systems, including the installation of high-flexibility, low-friction belts for baggage conveyors and shutting down service on escalators or moving walks when use patterns dictate. In addition, some airports have installed motor controls on moving walks that are load-sensitive, adjusting motors to meet demand. These controls reduce horsepower output and heat generated by the motor, which can extend service life and save energy (CAP 2004). Another way to reduce time on for systems such as moving walks is to use motion sensors (CAP 2003a, p. 22).

Cost/Payback/Savings: Literature notes a savings of 30% to 40% yearly energy consumption for upgraded conveyor belts and motor controls. Interviewees noted that quantifying energy savings when making an improvement can be difficult when systems are replaced owing to the complex of modern baggage screening systems.

Chapter Summary

The following practices were identified within the literature and survey data as practices that reduce energy costs and improve energy efficiency within small airport terminal electrical and mechanical systems (see Table 2).

- Seek out opportunities to replace carbon-based energy sources with renewable energy sources.

TABLE 2
ENERGY EFFICIENCY PRACTICES—ENERGY USE AND SYSTEMS

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[1]					PAYBACK[2,3]					%[4] Energy Savings
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown	
SOURCES													
Future energy sources that will reduce energy costs are largely based on solar power although in some parts of the country where biomass is available, cogeneration plants may also served to meet airport energy needs.	NON-RENEWABLE												
	As greater carbon controls put in place, airport terminals and other large commercial buildings will be affected by rising energy costs.	**Multiple Fuel Sources**											
	RENEWABLE												
	Solar and geothermal power hold promise for airports.	**Solar Photovoltaic**		■	■	■		■	■	■	■		
	METERING ENERGY USE												
	Metering technologies allow airport operators to initiate best management practices, monitor trends in energy use and improve building operations.	**Service Meter Data Baseline**		■				■					
		Advanced Meters		■				■					
		Electronic Sub-Metering			■			■					2.5 - 5%
	ENERGY RATES												
	By understanding utility rate structures and peak demand charges, airport terminals are better prepared to manage energy use and reduce costs.	**Rate Adjustment with Advanced or Sub-Meters**		■									
		Peak Load Shedding						■					
MECHANICAL HVAC													
Heating, Ventilation and Air Conditioning can consume around 40% of electrical energy at airports, with most of that being used by air condition systems.	HEATING - HYDRONIC												
	Retrofit of hydronic systems can improve efficiency by accurately sizing systems to meet heating demands.	**Solar Thermal**			■				■				
		Central Boiler Upgrades		■	■	■		■	■	■	■		
	ENERGY RECOVERY SYSTEMS												
	Heat recovery units increase heating and cooling efficiency by capturing or "recovering" energy from exhaust air that would otherwise be lost.	**Plate and Frame (Fluid) Heat Exchangers**			■			■					
		Air-to-air Heat Exchangers			■				■	■			
	COOLING												
	When replacement occurs due to age, it is very likely that new systems will save energy simply because of improvements to the technology.	**Central Chiller**			■				■	■			
	PACKAGED HEATING AND COOLING												
	Many small airports utilize packaged mechanical systems.	**Rooftop Air-Handlers**			■				■				
		Packaged Air-Conditioners			■				■				
		Economizer								■			
LIGHTING													
After Operational and Maintenance (O&M) improvements, lighting holds the greatest potential for energy savings at small airport terminals.	LAMP & FIXTURE RETROFIT												
	Lighting improvements are one of the most noticeable ways to save energy and, may elicit positive feedback from airport occupants and tenants.	**Upgrade to Flourescent Screw-type Bulbs**		■				■					
		Fluorescent Fixture Upgrade		■				■					
	CONTROLS & SENSORS												
	The unique geographic and operational considerations of each airport terminal as well as multiple types and manufacturers of lighting controls call for detailed study and planning for these improvements.	**Timer Lighting Controls**		■				■					
		Bi-Level Switching		■									
		Multi-Level Switching and Daylight Harvesting		■				■	■				
		Occupancy Sensors		■	■			■	■				20 - 75%
		Central Automated Lighting Control		■	■			■	■	■			
ELECTRICAL LOADS													
implementing controls that monitor loads can mitigate impacts of expanded systems.	VISUAL INFORMATION DISPLAYS												
	Used primarily for communication at airports, often in large banks making up composite displays. Also used for staff computers and entertainment or advertising.	**Display Shutdown**											
		Display Retrofit		■				■	■	■	■		
	CONVEYANCE SYSTEMS												
	Utilizing motor controls that are load sensitive, adjusting motors to meet demanad, can extend the life of the motor and save evergy.	**Baggage Conveyors, Escalators, Moving Walks**											≤40%

Notes:

1. Payback—time indicated refers to years required for improvement to return cost savings equivalent to project costs.
2. Cost information is based on energy rates for 2009 at respondent airport locations.
3. Cost can be defined as total project cost and not cost per square foot.
4. Percentage—value given represents a yearly reduction in energy or operations costs for that system or process.

- Document and manage energy use with metering systems.
- Seek improved energy rate structure and reduce peak load charges through communication with and programs by utility providers.
- Optimize existing heating and cooling systems with improved controls or retrofit with new, more efficient systems.
- Utilize heat recovery and economizers to save energy costs.
- Reduce energy used by lighting systems by replacing bulbs or fixtures and improving controllability with controls and sensors.
- Reduce energy use by major equipment by retrofitting with more efficient systems and implementing load sensing controls.

CHAPTER SIX

ENERGY EFFICIENCY PRACTICES: CONSERVATION AND BUILDING ENVELOPE

This chapter will discuss practices for improving energy efficiency at airports as they relate to energy conservation. It focuses primarily on the building envelope and practices that limit unwanted heat gain or energy losses through the roof, walls, windows, and openings.

BUILDING ENVELOPE

A key aspect of energy efficiency for any building is preventing energy loss or gain through the exterior envelope. If improvements are made to operations procedures or mechanical systems without considering improvements to the building envelope, energy may continue to be lost through unnecessary cooling loads and air infiltration.

The documentation of energy savings through building envelope improvements is difficult to quantify, especially in a retrofit scenario. Cost and payback for envelope improvements are discussed where respondent information was available.

A poorly designed envelope will impact occupant comfort and heating, cooling, and ventilation costs. An envelope design that is specific to climate, site, building use, and occupancy patterns can provide savings in the form of reduced cooling and heating loads and reduced investment in mechanical equipment. The cost of high-performance envelopes can be offset by smaller mechanical systems and through reduced energy costs over the life of the building (DOE 2009a).

REFLECTIVE MATERIALS TO REDUCE HEAT GAIN

Building materials contribute indirectly to energy consumption at airport terminals by absorbing or reflecting the sun's energy and increasing or decreasing cooling loads (CAP 2003a, p. 27). Reflectivity or albedo and "overall environmental life-cycle impacts and energy costs associated with the production and transportation of different envelope materials vary greatly" (DOE 2009a).

WEBLINK—Cool Roofs

U.S. Environmental Protection Agency

http://www.epa.gov/heatisland/resources/pdf/CoolRoofsCompendium.pdf

Cool Roof Rating Council—Codes and Rebate Info

Activities within the building, including occupants and systems, generate a significant amount of thermal loads that can often surpass energy entering the building from sunlight. These activities affect the rate at which the building gains or loses heat (DOE 2009a). When additional energy in the form of solar radiation heats the building, cooling loads increase. The primary materials strategy to reduce solar heat gain is to increase reflectance of the surface through installation of light colored or white roofing also called "cool" roofing. As noted by Seidenman and Spanovich (2008, p. 23), "the roof, in fact, presents an excellent opportunity for maximizing energy efficiency at an airport terminal, since it covers a tremendous amount of space."

"Reflective, or 'cool roofs,' can provide a building with up to 50 percent energy savings and reduce peak cooling demand by 10–15 percent" (Commonwealth of Pennsylvania n.d., p. 30).

GLAZING IMPROVEMENTS

Window glazing can affect heating and cooling requirements by managing the amount of light and heat that enters the building (DOE 2009a).

Solar heat gain through windows and skylights can be a problem at airports built without modern, insulated glass with low emissivity coatings. Cooling loads can be dramatically increased by direct sun on south and west facing glass during summer months.

Solar control window films are one strategy that provide a low-cost way to reduce heat gain. Films are typically attached to the interior surface of glazing. They utilize patterns of dots or stripes as well as reflective material to block sunlight. When films are applied, visibility is usually reduced but not impaired. Respondents noted a payback of 2 to 5 years and medium cost to install solar control window films.

INSULATION IMPROVEMENTS

Increasing insulation within the exterior envelope of a building can reduce heating and cooling costs by reducing the energy loss to the exterior of the building. Because most terminals are only one to three story buildings with large

footprints, the primary surface that can benefit from added or improved insulation is the terminal roof (Seidenman and Spanovich 2008).

Many airports use high-performance, low-slope roofs with long life spans. Building energy code requirements for roofing insulation have most likely changed since the last time a terminals roof was replaced and increasing insulation *R*-values may be required.

Roofing Replacement

Roofing replacement cost for buildings the size of airport terminals can be significant and varied owing to a wide range of factors; however, extra insulation can often be added with little difficulty (DOE 2009a). Survey respondents who have completed re-roofing projects with increased or high-performance insulation noted a payback of 2 to 5 years and medium cost.

Super Insulation

One insulation strategy for increased energy efficiency is to provide greater levels of insulation than required by building codes. Called "super insulation," *R*-values are often double typical specifications for a given region. This strategy serves to buffer the building from outside temperature swings and maintain interior temperatures for a longer period of time. Survey data show a limited response, with those using this strategy being located in southern or far northern climates, seeking to reduce heat gain or heat loss. Recent improvements at Juneau International Airport (JNU) include a "high-performance" envelope with an insulation *R*-value of 50 as part of a renovation and replacement of a 25-year-old roof (Martin 2009). Payback periods of 2 to 5 years with medium costs were noted for super insulation practices.

AIR MOVEMENT

At existing facilities, airport staff and consultants have a limited ability to modify many of the envelope components without major renovations. Of all the envelope strategies noted in this chapter, "reducing outside air infiltration into the building by improving building envelope tightness" may be the most feasible (DOE 2009a). Primary methods of reducing air infiltration include closure of envelope penetrations and controlling doors and openings.

Reducing Infiltration and Loss

One airport noted that a variety of security, communications, and data equipment attached to or located on the exterior of their building had led to multiple penetrations through the envelope that wasted energy. By sealing these openings, energy savings were expected. Payback periods of 2 to 5 years with medium costs were noted at Newark Liberty International Airport (EWR) for this improvement.

Controlling Doors and Openings

Multiple respondents noted the utilization of high-speed, roll-up doors at high traffic openings such as baggage handling areas to reduce heat loss and manage interior temperatures. Respondents noted a payback of 0 to 5 years and a medium cost to implement opening improvements.

Chapter Summary

The following practices were identified within the literature and survey data as building envelope improvements that reduce energy costs and improve energy efficiency within small airport terminal buildings (see Table 3).

- Reduce solar heat gain and lower cooling loads by increasing reflectivity of exterior surfaces.
- Utilize window films or other retrofit shade devices to reduce solar heat gain and improve occupant comfort.
- Take advantage of infrequent roof replacement by increasing levels of insulation.
- Monitor and manage exterior openings to reduce air movement and heating or cooling energy losses.

TABLE 3
ENERGY EFFICIENCY PRACTICES—CONSERVATION AND BUILDING ENVELOPE

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[1]					PAYBACK[2,3]					%[4] Energy Savings
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown	
BUILDING ENVELOPE													
One key aspect of energy efficiency on any building is preventing energy lost or gain through the exterior envelope.	MATERIALS												
	Building materials contribute indirectly to energy consumption at airport terminals by absorbing or reflecting the suns energy and increasing or decreasing cooling loads.	**Reflective Materials to Reduce Heat Gain**											≤ 50%
	GLAZING												
	Window glazing can manage the amount of heat that enters the building and reduce cooling loads.	**Films to Reduce Solar Gain**			■				■				
	INSULATION												
	The primary surface that can benefit from added or improved insulation is the roof of the terminal.	**Roofing Retrofit**			■				■				
		Super-Insulation			■			■	■				
	AIR MOVEMENT												
	Reducing outside air infiltration into the building by improving building envelope tightness is usually quite feasible.	**Reducing Infiltration & Loss**			■				■				
		Controlling Doors and Openings			■			■	■				

*Notes:

1. Payback—time indicated refers to years required for improvement to return cost savings equivalent to project costs.
2. Cost information is based on energy rates for 2009 at respondent airport locations.
3. Cost can be defined as total project cost and not cost per square foot.
4. Percentage—value given represents a yearly reduction in energy or operations costs for that system or process.

CHAPTER SEVEN

STRATEGIES FOR IMPLEMENTATION

FACTORS THAT AID IN IMPLEMENTATION OF ENERGY EFFICIENCY PRACTICES

Economics

When asked to identify factors that have aided in the implementation of energy efficiency projects, funding, especially that outside the regular budget, was noted as primary, especially at smaller airports responding to the survey. General economic factors related to escalating operation costs also have increased support for energy efficiency projects and caused airline tenants to "aggressively support investments that reduce operating costs," noted one airport manager. By leveraging this growing demand in support of energy efficiency projects, an airport may be able to increase the scope of a project, make the project more competitive within a state or federal grant process, and/or find broad support for improvements within the airport administration.

Staff Behavior

Other, less economically focused factors such as staff behavior and general social attitudes toward sustainability also play a role in the success of an energy efficiency project. With more focused attention on sustainability issues within the last decade and the documented impacts by airplanes on carbon emissions, energy efficiency projects have benefited over other capital projects owing to their greater value. Staff behavior has most certainly been affected as well, with Americans overall being more conscious of sustainability within their workplace. Although less quantifiable, modifications to staff behavior could be assumed to be low cost and high value.

Technology and Design

A third major category of factors aiding in implementation are those associated with technology or design. As noted in the planning section, by considering energy efficiency in the design of every capital project and within operations, the need to retrofit is eliminated or reduced and payback can be fully evaluated before expenditure. With major mechanical or electrical system upgrades, evaluation of efficiency is principle to the project and, as such, generally brings low additional design cost.

Highlight Value

A key implementation strategy noted by one major airport is to acknowledge and highlight the "multiple value streams," including economic, environmental, and operational, that accrue with energy efficiency projects when presenting programs and improvements to airport staff and other stakeholders.

Designate Energy Efficiency Advocates

Unique factors that have improved energy efficiency project success at large airports, including TPA, MSP, and DFW, include special programs focused on sustainability and goal setting processes.

To ensure that building systems operate as specified and designed, a commissioning framework and "energy advocate" or committee should be present in early phases of the design process (CAP 2003b, p. 9) and throughout project bidding and implementation. One interviewee noted that this strategy helps avoid "value-engineering" out energy saving design strategies to reduce project development costs at the expense of increased operations costs.

Dedicated Energy Managers

Although the management of energy systems at smaller airports is usually very limited (with most responsibilities falling on the airport manager), dedicating staff time to monitoring energy use can provide aid in implementation by collecting accurate data for future energy efficiency projects and ensuring that equipment is performing at optimal efficiency. A majority of airports surveyed do not dedicate full-time staffing toward energy management, even at larger facilities; however, energy management is often under the purview of airport staff.

PROJECT JUSTIFICATION

Justification for energy efficiency projects is often a challenge owing to a number of factors. Each project and airport terminal is unique, with variable fuel and electrical costs, climate, building size, mechanical and electrical systems, etc. These factors, coupled with limited data about energy efficiency

project upfront costs and payback and constantly changing technology, make finding and documenting appropriate supporting information to justify a project challenging.

Data

As mentioned elsewhere in this report, data about existing energy costs and use for an airport terminal is the primary way to understand what type and where improvements will be most successful. These data are best gathered through an energy audit or commissioning process that approaches the terminal systems holistically. Larger airports participating in the survey indicated that funding for commissioning or other technical evaluation is often supported by utility companies, with some utilities providing consultants as well as funding.

Feasibility Studies

Small airports can turn to a variety of sources for feasibility studies including cost–benefit analysis and ROI analysis performed by airport staff, case studies of similar projects, or other technical literature from consultant and industry reports. These resources can provide support with examples of project processes, comparable technology, and documented payback, but typically require additional staff analysis and packaging to support a particular project.

Demonstration Projects

An alternative strategy and one that may be especially viable at airports located in areas of unique weather; that is, strong winds or excessive sun, is to fund small-scale demonstration projects (wind or solar) in support of larger, terminal-wide installations. Demonstration mock-ups such as window films and lighting systems can also be considered for interior projects as a part of retrofits or remodels.

Included with Other Capital Projects

Interviews identified that most energy efficiency projects are usually not stand-alone projects and therefore required less specific justification because the core project had other, non-energy benefits. In general, the chances of implementing an energy efficiency project are greater when that project is a part of an existing, funded project.

FUNDING CHALLENGE

As might be expected, the major challenge to implementation of energy efficiency projects at airports surveyed is funding. With no recent increases in Airport Improvement Program (AIP) funding, limited passenger facility charges owing to low enplanements, and a greater focus on security improvements, funding dollars for energy efficiency projects at smaller airports are limited (Schofield 2009).

Local level grants by energy providers and other state organizations usually support smaller projects or portions of major upgrades. These funding sources continue to become more available, especially in states with aggressive sustainability targets and legislation such as California.

If adequate funding were available, survey respondents indicated that improvements that reduce operations costs would receive priority. Second to operations costs were additional control of systems, which may be more easily attainable for smaller airport terminals owing to their (relatively) low building square footage, and simplicity of systems.

Funding for energy efficiency projects at most airports surveyed is largely handled within the regular budget process, either through operations or capital expenditures. In many cases, for smaller airports, budget dollars are FAA/AIP funding; however, the financial structure of larger airports often includes other sources. Depending on the type or duration of project, lamp retrofit or visual display retrofit for example, energy efficiency improvements may be included in normal O&M budgets for little or no cost. In addition, at the end of the fiscal year, smaller projects such as lamp or fixture retrofits may be addressed by left over operational dollars.

Grants

In addition to FAA funding such as AIP entitlement grants, other governmental agencies such as the EPA, DOE, and U.S.DOT have provided grants to airports. Recently, an Energy Efficiency and Conservation Block Grant from DOE was awarded to support construction of renewable energy systems at an airport on St. Croix, U.S. Virgin Islands (DOE 2009c).

Ongoing terminal improvements including a ground-source heat pump mechanical system at Juneau International Airport were funded in part by grants through the state of Alaska Legislature (Palmer and Fritz 2008). Additional funding for the improvements came from local Capitol Improvement Plan (CIP) funds and a sales tax.

WEBLINK—Financing Energy Efficiency

DSIRE—Financial Incentives for Energy Efficiency:

http://www.dsireusa.org/summarytables/finee.cfm.

Financing Energy Efficiency Improvements:

http://cepm.louisville.edu/Pubs_WPapers/practiceguides/PG21.pdf

Chapter Summary

The following methods were identified within literature and survey data as ways to implement practices that reduce energy costs and improve energy efficiency at small airport terminals.

Box 16 Financing Energy Efficiency

Allison describes a variety of financing mechanisms including "internal financing, debt financing, lease and lease-purchase agreements, energy performance contracts, and utility incentives" (Allison 2008, p. 8).

Traditional internal capital methods are "often the simplest way to pay for energy efficiency projects" because all savings are gained by the organization (Allison 2008, p. 8). Another alternative is debt financing; however, it is noted that this method can have greater administrative complexity (Allison 2008, p. 8).

Other external financing relationships include "leasing and lease-purchase agreements [which] help organizations get around the high, up-front costs of new, energy-efficient equipment and, in some cases, include guaranteed savings clauses" (Allison 2008, p. 8).

As mentioned in chapter two, ESCO performance contracts can include financing for improvements as well as "equipment purchases, and maintenance" (Allison 2008, p. 8)

- Leverage the growing demand for cost savings in support of energy efficiency projects to increase the scope of a project, make the project more competitive, and find support within the airport administration.
- Take advantage of changes in social attitudes that support sustainability to stress the greater value of energy efficiency projects toward overall airport carbon reductions.
- Consider energy efficiency in the design of every capital project and within operations.
- Highlight the "multiple value streams," including economic, environmental, and operational, that accrue with energy efficiency projects when communicating to stakeholders.
- Utilize commissioning to ensure that new or retrofit building systems operate as specified.
- Designate an energy advocate within the project teams to monitor and support energy efficiency goals.
- Utilize data from audits, feasibility studies, and demonstration projects to justify new projects.
- Consider grants from state and local utilities as well as alternative funding structures such as ESCO's agreements to fund energy efficiency projects.

CHAPTER EIGHT

NEW TECHNOLOGIES, INNOVATION, AND LONG-TERM PAYBACK

This chapter discusses emerging technologies, innovative project delivery, and policy trends that will impact energy efficiency at airports in the future. Unique or innovative practices and those with long-term payback included solar PV, wind energy systems, and high-performance windows.

EMERGING TECHNOLOGIES

Solar Thermal and Photovoltaics

As identified more than 20 years ago in the Bruntland report, the technology for solar thermal and solar electric technologies is constantly improving and "it is likely that their contribution [to energy production] will increase substantially" (Bruntland 1987, p. 144).

> The need for a steady transition to a broader and more sustainable mix of energy sources is beginning to become accepted. Renewable energy sources could contribute substantially to this, particularly with new and improved technologies, but their development will depend in the short run on the reduction or removal of certain economic and institutional constraints to their use (Bruntland 1987, p. 145).

Airport terminals possess distinct advantages that position them well for implementation of solar technologies in the future including large roof areas and limited shading from vegetation.

Fresno–Yosemite and Phoenix Airports have installed large, greater than 1 MW, projects.

> Although prices for electricity from photovoltaics may not become widely competitive with wholesale prices for electricity from conventional generating technologies within the next 25 years, they may be competitive with high retail electricity prices in sunny regions (EIA and DOE 2009).

Power Purchase Agreements for Photovoltaic Systems

In addition to owner-installed and managed roof-top PV installations, alternative leasing models are being tested across the country, with one of the largest being initiated by the utility, Southern California Edison and their Solar Roofs Program. Southern California Edison or a private corporation will "own, install, operate and maintain" rooftop systems on existing commercial or public rooftops, leasing space from and selling power to building owners through contracts known as power purchase agreements. This strategy takes advantage of large, underutilized roof areas within the established electrical grid and uses them for electrical production (Coughlin 2009).

With large roof areas on terminal buildings, hangers, and parking structures, and very little shade from surrounding buildings, airport terminal roof tops are often prime candidates for large-scale PV installations—especially as panel efficiencies increase and costs decrease (Seidenman and Spanovich 2008).

Quoting California Public Utilities Commission Commissioner John A. Bohn, "Unlike other generation resources, these projects can get built quickly and without the need for expensive new transmission lines. And since they are built on existing structures, these projects are extremely benign from an environmental standpoint, with [limited] land use, water, [and] air emission impacts" (California Public Utilities Commission 2009, p. 2).

Because a private investment group and solar developer pay for installation, all up-front capital costs are avoided; however, agreements are legally complicated and usually require an agreement to purchase power at a fixed rate for 20 years or more (Coughlin 2009).

Geothermal or Ground-Source Heat Pumps

Ground-source heat pump (GSHP) is the name for "a broad category of space conditioning systems that employ a geothermal resource—the ground, groundwater, or surface water—as both a heat source and sink. GSHPs use a reversible refrigeration cycle to provide either heating or cooling" (DOE 2007). By replacing old or inefficient direct expansion mechanical systems with GSHP, significant savings and additional flexibility within the system can be achieved.

Very limited use was noted in the survey with only one major airport providing cost data. These data indicated a 2- to 5-year payback and medium level of investment. Other sources indicated longer payback terms of 4 to 13 years and savings of 25% to 30% on energy consumption (Turner et al. 2007, p. 14; DOE 2008).

Ongoing improvements at the JNU airport include the addition of GSHP systems and envelope retrofits. Although the $1 million cost of the GSHP system is close to 20% of the annual operations budget, a combination of grants, legisla-

tive appropriations, and facility fees coupled with expected savings of at least $80,000 per year in energy costs, mean an expected payback of just over 6 years (Martin 2009). Geothermal ice and snow melt systems in exterior pavements are expected to bring additional savings owing to reduced equipment maintenance costs, labor, and ice removal chemical expenses (Martin 2009).

Box 17 Implementing Geothermal Space Conditioning

Juneau International Airport (JNU) and the surrounding community typically heat with diesel fuel owing to the landlocked geography and therefore are very sensitive to fuel prices. When the airport began evaluating a terminal rehabilitation and expansion, fuel prices were rising, which made operating costs a determining factor in the decision to install a ground source heat pump or geo-thermal system, one of the first systems in the area. With this system coming on line in the late fall of 2009, the airport is already looking ahead to future improvements. Another geothermal system, this one a horizontal loop field, was installed for a future maintenance building as the building site was disturbed during a separate earthwork project (see Figures 12 and 13).

Bemidji Regional Airport (BJI), located in northern Minnesota, is taking a similar approach, and utilizing large land areas that airports have available to plan for a geothermal system. This system will be a vertical well-field installed adjacent to taxiways to serve an expanded terminal building, as well as a renovated Aircraft Rescue and Fire Fighting (ARFF) facility.

Cogeneration of Heat and Electricity

The survey found no use of cogeneration technology by survey respondents. Literature sources indicated utilization at other airports, including Toronto, which built a "three turbine cogeneration plant" (Schwartz 2009).

FIGURE 12 Geothermal well field. Well fields installed below existing pavements at Juneau International Airport (*Courtesy:* JNU).

FIGURE 13 Geothermal system installation.

The "use of cogeneration is not a simple decision because of fluctuating natural gas and electric prices and high capital costs" (Turner et al. 2007, p. 6).

Micro Wind Turbines

Small-scale wind turbine installation, such as PV installation, has been considered as a supplemental energy source for airport terminals. Currently, their implementation is challenged by low electricity rates, which can significantly extend payback periods.

As a test case, on-site, parapet-mounted wind turbines were recently installed at MSP Airport. Although long-term data are not yet available, payback periods of greater than 10 years are expected at this time (see Figure 14).

Peak Shifting Thermal Storage

To avoid paying peak demand charges for energy during the most intensive months and days of the year, some airport respondents utilize peak-shifting thermal storage. This practice takes energy at off-peak times to heat or cool a material

FIGURE 14 Micro scale wind turbines. Parapet mounted turbines mounted on the airport fire station at MSP.

(usually water) that is then used for heating or cooling energy during peak times. A second method of peak shifting involves switching power generation to on-site diesel or natural gas powered generators or PV arrays, which reduces demand for utility-provided power. If generators are used, local air quality may be affected.

Considerable cost savings can be realized with thermal storage technology if utility rate schedules have penalties for high peak electrical demand (Turner et al. 2007, p. 12). Thermal storage retrofits have an estimated payback of 3 to 10 years (Turner et al. 2007, p. 14).

Windows

Future window technologies will continue to improve the insulating properties of window systems and increase the responsiveness of building envelopes to daily changing climatic conditions.

Ways that windows may continue to contribute to building energy efficiency include:

- Insulation Filled Glazing—"There are several options for highly insulating windows with aerogel, honeycombs, and capillary tubes located between glazing panes. These materials provide diffuse light, not a clear view" [Center for Sustainable Building Research—University of Minnesota (CSBR-UMN) 2007].
- Dynamic "Smart" Windows—"These facade systems include switchable windows and shading systems such as motorized shades, switchable electrochromic or gasochromic window coatings, and double-envelope window-wall systems that have variable optical and thermal properties that can be changed in response to climate, occupant preferences and building system requirements" (CSBR-UMN 2007).
- Building Integrated Photovoltaics—"Photovoltaic vision glass integrates a thin-film, semitransparent photovoltaic panel with an exterior glass panel in an otherwise traditional double-pane window or skylight" (CSBR-UMN 2007).

"Green" or Renewable Power

Two survey respondents indicated that renewable power was purchased by the airport in substitution for carbon-based power. This arrangement may reduce utility costs during peak periods and supports greater investment by utilities in renewable power systems.

EMERGING PROJECT DELIVERY

As energy efficiency and sustainable design become more integrated into new and existing buildings, project delivery methods are adapting to accommodate the added complexity of energy systems and building management.

Integrated Design and Building Simulation

Integrated design is a departure from typical design and construction processes that brings disciplines together early in the process, holistically evaluating the design in terms of energy performance and other factors. It can "enhance air quality, lighting, thermal environment and other key aspects of a building's indoor environment" (Griffith et al. 2007, p. 9). The integrated team requires collaboration between all stakeholders.

"The expansion of the 'efficiency resource' is also accelerating as designers realize that whole-system design integration can often make very large (one or two order-of-magnitude) energy savings cost less than small or no savings, and as energy-saving technologies evolve discontinuously rather than incrementally. Similarly, rapid evolution and enormous potential apply to ways to market and deliver energy-saving technologies and designs; research and development can accelerate both" (Lovins 2004, pp. 384–385).

EMERGING POLICY

Emerging Energy Guidelines

Federal regulations within the Energy Policy Act of 2005, as well as state-level high-performance energy codes, will continue to push private and public sector buildings to improve energy efficiency. Federal standards noted here by literature sources represent one future direction that could have significant impacts on buildings such as airport terminals.

- EPACT Section 103—all federal buildings must be metered by 2012.
- EPACT Section 1251—net metering.
- EPACT Section 1331—support for $1.80 per square foot tax deduction for sub-metered properties (Millstein 2008).

State by state, policies regarding energy efficiency for buildings and utilities continue to develop rapidly. The American Council for an Energy-Efficient Economy has identified major issues regarding energy efficiency in most states.

WEBLINK—State Energy Efficiency Policy Database
American Council for an Energy-Efficient Economy:
http://www.aceee.org/energy/state/index.htm

ZEB—Net Zero Energy Buildings

"Designing a building in such a way that energy efficiency and on-site production convert it from an energy consumer to an energy producer lies at the heart of the zero-energy building (ZEB) concept" (Griffith et al. 2007, p. 1).

Studies by the National Renewable Energy Laboratory on ways to achieve net zero energy building "indicate that the amount of energy that can be saved by efficiency measures is comparable to the amount that can be generated by rooftop PV panels and that pursuing both is important for reaching the ZEB goal" (Griffith et al. 2007, p. 64).

Because of the many energy-intensive systems at airport terminal buildings, they may be challenged to achieve net zero energy status. Interviewees indicated that strategies learned from the ZEB concept will enable airport managers to better control the escalating costs of energy.

Chapter Summary

The following practices were identified within literature and survey data as emerging technologies, policies, and trends that will impact energy efficiency at airports in the future.

- Renewable and on-site energy technologies such as solar PV and geothermal space conditioning coupled with innovative financing and purchasing agreements have already reduced energy costs at some airports.
- Envelope materials and mechanical systems are becoming more adaptable and responsive to changing environmental conditions.
- Design delivery methods for new or complex projects often include integration of analysis and energy modeling.
- Federal and state energy guidelines continue to endorse and require energy efficiency.
- Airport terminal buildings will continue to be challenged to manage energy use in the face of escalating energy costs and demands for energy neutral buildings.

CHAPTER NINE

CONCLUSIONS

The survey responses revealed that all airport terminals had implemented at least one type of low/no-cost energy efficiency improvement, usually focused on operations or lighting retrofits.

Planning for energy efficiency improvements can be a complex task, especially for terminal managers at smaller airports. By embedding energy efficiency goals within long-range plans or creating efficiency programs within operations or development departments, airport stakeholders can ensure that all projects consider energy efficiency. Other practices cited for planning energy efficiency improvements include:

- Searching out other airport managers, consultants, local ordinances, and utility programs, as well as national standards as knowledge resources for planning energy efficiency projects.
- Utilizing utility grants and consultant contracts to perform audits and feasibility analysis.
- Focusing limited budgets with phased implementation or departmental prioritization.
- Testing small-scale projects for larger-scale implementation.
- Enforcing efficiency with tenant and airport design standards.
- Grouping projects with short- and long-term payback to use early cost savings as support for other investments.
- Considering airport terminal energy efficiency projects in a holistic manner and seeking out synergies between improvements.

Data collection is paramount to most improvements and without an energy audit, or other building baseline information, determining where energy efficiency projects will have the greatest impact on energy costs is challenging. Automation systems provide an invaluable mechanism to monitor trends and payback information for use in additional energy efficiency projects.

Operations and maintenance (O&M) practices have received considerable attention in many reports and best practices manuals. These data reinforce both the rapid savings benefit and ease of implementation that have previously been attributed to O&M energy efficiency practices and outlines practices such as commissioning, maintenance scheduling, staff behavior, and intra-airport communication as keys to successful energy cost reduction.

Major reductions to energy expenses were found through retrofit of mechanical and lighting systems when these critical functions were replaced, upgraded, or re-commissioned with new controls and building automation.

Funding was identified as the major barrier to implementation of energy efficiency improvements for all respondents. Tactics for funding and implementation for those airports that have successfully reduced energy costs varied. With their limited funding resources, small airports may first work to include energy efficiency into O&M programs and lighting systems. Another way to leverage energy efficiency dollars is by partnering with other existing county or city projects and utility companies.

Major airports have the scale, budget, and staff complexity to test energy efficiency operations and retrofit projects and may be used as a reference for smaller airports. Communication within and between airports is strongly encouraged.

Local utility companies have assisted airport operators in reducing energy costs by conducting no-cost or low-cost energy audits and by providing grants or rebates for demonstration projects or energy efficiency upgrades. Positive partnerships with utility companies were noted by many respondents as an important part of an energy efficiency plan. Many of these utility incentives along with government incentives can be found in one location—The Database of State Incentives for Renewable and Efficiencies (http://www.dsireusa.org/summarytables/finee.cfm).

Airports are positioned to utilize renewable energy technology as a result of their high roof surface area and relationship with utility companies as major users of energy.

An important observation that must be understood concerning the entirety of this report is that the diversity of strategies and relative costs noted in the survey response asserts that no two airports are equal, nor will they benefit the same from any improvement. The best reference for an airport terminal can be found in baseline conditions that exist today on site.

No further research is identified at this time other than monitoring airport energy efficiency improvements and updating synthesis of practice as new tools or regulations warrant.

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GLOSSARY OF TERMS, ACRONYMS, AND ABBREVIATIONS

TERMS

Advanced meters—those that have the capability to measure and record interval data (at least hourly for electricity), and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. EPAct Section 103 requires at least daily data-collection capability (Sullivan et al. 2007, p. 2.1).

Boardings—see enplanements

Commissioning—according to ASHRAE Guideline 1-1996, the process of ensuring that new systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent.

Datalogger—a stand-alone, electronic data gathering device that uses sensors to collect equipment information over time. Data collected could include temperature, pressure, current, humidity, or other operational information.

Diagnostic monitoring—practice of collecting data on equipment operation over a period of time for the purpose of assessing the equipment performance. These data may be obtained through a *datalogger* or an *energy management system.* These data may consist of time-series or change-of-value data that can be collected for digital points such as temperature, pressure, or status.

Energy assessment—combined evaluation of equipment and operations; investigation of systems in existing buildings with the goal of replacing or retrofitting equipment. This is a quick process that may include building simulation and results in a list of energy conservation measures that involve significant capital investment.

Energy audit—investigation of systems in existing buildings with the goal of replacing or retrofitting equipment. This is a quick process that may include building simulation and results in a list of energy conservation measures that involve significant capital investment.

Energy Management System—automatic system used for controlling equipment in a building. Most likely this will be a computer-based system, including either pneumatic or digital components, or both.

Enplanements—domestic, territorial, and international revenue passengers who board an aircraft in the states in scheduled and nonscheduled service of aircraft in intrastate, interstate, and foreign commerce and includes in-transit passengers (passengers on board international flights that transit an airport in the United States for non-traffic purposes).

Heat gain—increase of heat within a given space as a result of direct heating by solar radiation and of heat radiated by other sources such as lights, equipment, or people.

Investment grade audit—audit that incorporates the aspects of a traditional *energy audit* plus a risk assessment that evaluates the impact that occupancy, management, maintenance, and operational behavior will have on energy efficiency measures.

O&M assessment—systematic method for identifying ways to optimize the performance of an existing building. This assessment involves gathering, analyzing, and presenting information based on the building owner or manager's requirements.

O&M consultant—consultant who is hired by the building owner to assist with an *O&M assessment* or *retro-commissioning* in a management or oversight role. This consultant guides the owner through development and distribution of a *Request for Proposal,* through commissioning provider selection, and possibly assists in creating a program for retro-commissioning implementation at all owner facilities.

Payback—length of time that an energy efficiency improvement will take to provide the full return on investment. For example, if a $1,000 investment will yield $1,000 in energy or maintenance savings by the end of the first year, that investment has a 1-year payback.

Peak electrical demand—peak electrical demand is the maximum instantaneous load or the maximum average load over a designated interval of time, usually 15 or 30 min measured by meter by the utility or power provider. Also known as peak power.

Peak load shedding—defers system loads from peak periods to periods of low demand. The result is a flattening of the system load schedule, thus decreasing demand charges from the electric utility. Design strategies that reduce the peak load are often referred to as "peak shaving."

Preventive maintenance program—program that is implemented to address equipment maintenance issues proactively. The goal of such a program is to perform maintenance tasks on a regular schedule so as to maximize the operational efficiency and lifetime of the equipment.

Real-time pricing—energy prices that are set for a specific time period on an advance or forward basis and that may change according to price changes in the generation spot market. Prices paid for energy consumed during these periods are typically established and known to consumers a day ahead ("day-ahead pricing") or an hour ahead ("hour-ahead pricing") in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall (Sullivan et al. 2007).

Retro-commissioning—for an existing building, the process of assessing, analyzing, and upgrading its operational performance. A preliminary step in the retro-commissioning process is the *O&M assessment.* Retro-commissioning usually results in a number of low-cost or no-cost activities that save energy while maintaining or improving comfort.

Solar heat gain—increase of heat within a given space as a result of direct heating by solar radiation.

Time-of-use pricing—energy prices that are set for a specific time period on an advance or forward basis, typically not changing more often than twice a year (summer and winter season). Prices paid for energy consumed during these periods are pre-established and known to customers in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower-cost period, or reducing consumption overall. The time periods are pre-established, typically include from two to no more than four periods per day, and do not vary in start or stop times (Sullivan et al. 2007).

Trend log—log of data that is collected through an *energy management system.* These data may consist of time-series or change-of-value data that can be collected for digital points such as temperature, pressure, or status.

Value commissioning—focus on the most frequently available re-commissioning/retro-commissioning opportunities with the highest payback as a part of daily O&M (Sullivan et al. 2004).

ACRONYMS

ACEEE	American Council for an Energy-Efficient Economy
AIP	Airport Improvement Program
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BAS	Building automation system
BCS	Building control systems
CIP	Capital Improvement Plan
CFL	Compact fluorescent light
CRT	Cathode ray tube
DFW	Dallas/Fort Worth International Airport
EMCS	Energy Management Control System
EPACT	Energy Policy Act
ESCO	Energy Service Company
HID	High intensity discharge
HVAC	Heating, ventilating, and air conditioning
IMACS	Intelligent Monitoring and Control System
LCD	Liquid crystal display
LED	Light-emitting diode
LEED©	Leadership in Energy and Environmental Design
MAC	Metropolitan Airports Commission
MECP	MAC Energy Conservation Program
MSP	Minneapolis–St. Paul International Airport
NREL	National Renewable Energy Laboratory (U.S. Department of Energy)
O&M	Operation and maintenance
OABA	Open Architecture Building Automation
PECI	Portland Energy Conservation, Inc.
PV	Photovoltaics
ROI	Return on Investment
RTU	Roof-top units
SAGA	Sustainable Aviation Guidance Alliance
SCADA	Supervisory Control and Data Acquisition
Sea–Tac	Seattle–Tacoma International Airport
VAV	Variable air volume
VFD	Variable frequency drive
ZEB	Zero energy buildings

ABBREVIATIONS

ft	foot
g	gram
h	hour
in.	inch
km	kilometer
kW	kilowatt
L	liter
lb	pound
mg	milligram
mi	mile
min	minute
mL	milliliter
s	second
ft^2	square foot
yd	yard

APPENDIX A

Method and Survey Response

LITERATURE REVIEW

A literature review was conducted to identify best practices for energy efficiency and generate categories and questions about low-cost practices for the survey questionnaire. In addition, the review collated data from previous studies about low-cost energy efficiency improvements and provided supplemental information to support results of the survey.

A wide variety of sources were referenced including aviation, transportation, and construction journal articles; aviation industry and government reports; university and institution studies; industry conference proceedings; and national, state, and public agency websites.

The results of the literature review appear throughout the document, as both highlighted information and general content to support the respondent's strategies for reducing energy costs through efficiency improvements. Information from the literature review is cited and sources are listed in the References.

SURVEY

A questionnaire was developed to obtain information about the planning and implementation of energy efficiency practices at targeted airports.

The survey consisted of multiple choice and yes/no questions. For specific practice-oriented questions, participants were encouraged to quantify "estimated payback" and "cost to implement" by checking supplemental boxes. Survey participants were also encouraged to elaborate on responses within blank text boxes

The results of the survey were used throughout the report to describe or reference practices and cost information. Primary formats of these results found in the report include:

- Figures or charts summarizing results
- Highlighted areas of text describing actions from specific airports in greater detail or topics of interest supplemental to the main report
- A general discussion of results pertaining to specific topics.

See Appendix B for more information and specific questions.

Format and Distribution Methods

To ensure easy access to the survey it was translated into Portable Document Format (PDF) for electronic distribution. This allowed each survey to be coded for distribution to a specific airport. It also allowed immediate return of data to the consultant to expedite preparation of the report. Lastly it preformatted the data to that particular airport, allowing tracking of responses and management of completed surveys.

Target Audience

The TRB panel and staff provided a list of candidate terminals, which was supplemented by the research team to total 20 airport operators with direct knowledge of airport terminals and energy efficiency measures. To obtain data salient to small airport terminals, the researchers were directed to contact small hub and commercial service airports to determine if they had completed applicable projects and invited them to participate in the survey. The final list was not intended to be a random sample and may not present an unbiased or broad perspective of energy efficiency improvements. For instance, some respondents are also members of the TRB panel.

SURVEY RESPONSE

Of the 20 airports required to submit information, 20 responses were received, representing a 100% response rate. The 20 airports that responded to the survey are referred to as survey respondents throughout the report. Small hub, non-hub, and commercial service

Box A1 Airport Classification

US Code Title 49 §47102 categorizes airports into large hub, medium hub, small hub, and non-hub, according to annual passenger boardings or enplanements. The categories are defined as follows:

- Large hub airport—a commercial service airport that has at least 1.0% of total U.S. passenger boardings.
- Medium hub airport—a commercial service airport that has at least 0.25% but less than 1.0% of total U.S. passenger boardings.

In this report large and medium hub airports were combined into one category. These combined categories identify airports with more than 1.9 million enplanements.

- Small hub airport—a commercial service airport that has at least 0.05% but less than 0.25% of total U.S. passenger boardings (more than 380,000 and less than 1.9 million enplanements).
- Non-hub airport—a commercial service airport that has less than 0.05% of total U.S. passenger boardings (more than 10,000 and less than 380,000 enplanements).

Nonprimary commercial service airports were also contacted. This category is defined as follows:

- Commercial service airport—a publicly owned, commercial service airport that has at least 2,500 and fewer than 10,000 passenger boardings each year and receives scheduled passenger service.

The respondents represented the following classifications of airports (see Figure A1):

- 8 large and medium hub (40%)
- 5 small hub (25%)
- 4 non-hub (20%)
- 3 commercial service (15%)

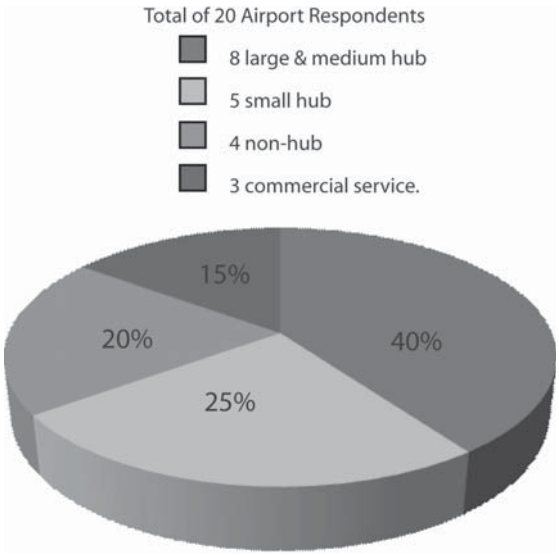

FIGURE A1 Airport size graph.

airports represented 60% of responses. See Box A1 for more about airport classification.

AIRPORT TERMINAL SQUARE FOOTAGE

The 20 airports provided terminal size as a reference. The respondents reported the following range of terminal sizes:

- large/medium hub: 400,000 ft^2 to 6 million ft^2
- small hub: 140,000 ft^2 to 600,000 ft^2
- non-hub: 54,000 ft^2 to 160,000 ft^2
- commercial service: 5,000 ft^2 to 21,000 ft^2

Although there were a number of large and medium hub airports that provided information, many energy efficiency practices are scalable to smaller airport terminal buildings.

INTERVIEWS

A total of 13 airports were contacted for follow-up interviews to discuss energy efficiency practices that have been implemented in greater detail. Of these 13, 12 were able to provide additional information.

Airport interview participants:

- Bemidji Regional [BJI]
- Dallas/Fort Worth International [DFW]
- Dickenson–Theodore Roosevelt Regional [DIK]
- Fresno Yosemite International [FAT]
- Juneau International [JNU]
- Montgomery Regional [MGM]
- Minneapolis/St. Paul International [MSP]
- Eastern Oregon Regional at Pendleton [PDT]
- Mid-Ohio Valley Regional—Parkersburg [PKB]
- Reno/Tahoe International [RNO]
- Lambert/St. Louis International [STL]
- Tampa International [TPA].

These interviews were conducted as person-to-person telephone calls and teleconferences that included additional research staff and/or additional airport staff and airport energy consultants. Content from interviews is incorporated throughout the report and as text boxes to highlight specific practices or strategies of note.

Box A2 Geographic Location of Respondents

The FAA monitors and regulates the national airspace through 9 administrative regions: Alaska, Central, Eastern, Great Lakes, New England, Northwest Mountain, Southern, Southwest, and Western–Pacific.

The 20 responses were from airports located in all 9 of the FAA administrative regions and 16 different states: Alabama, Alaska, Arizona, California, Florida, Iowa, Michigan, Minnesota, Missouri, Nevada, North Dakota, Oregon, Texas, Vermont, Virginia, and West Virginia.

APPENDIX B

Airport Energy Efficiency and Cost Reduction Survey

SURVEY RECIEVED INTERVIEW DATE	**SURVEY QUESTIONNAIRE FOR AIRPORTS** ACRP SYNTHESIS S10-04 Airport Energy Efficiency and Cost Reduction	MDA USE ONLY SURVEY CODE

The Transportation Research Board's Airport Cooperative Research Program has commissioned a study on airport terminal energy efficiency and cost reduction. One objective is to identify practices which have been particularly effective at small airport terminals. As someone with experience in this area, we would like to have your input. Please be assured that your responses will be kept in confidence, to be aggregated with all other responses.

INSTRUCTIONS:

COMPLETE BY EMAIL: complete survey electronically, click email button, follow prompts

COMPLETE BY FAX: complete survey electronically, print, fax to (612) 337-0001.

COMPLETE BY USMAIL: complete survey electonically, print, mail to:

Joel Stromgren, AIA
Miller Dunwiddie Architecture
123 N. 3rd Street, Ste 104
Minneapolis, MN 55401

QUESTIONS - PLEASE CONTACT Joel Stromgren at 612 - 278 - 7690

THIS FORM IS BEST VIEWED IN ADOBE READER 9
THIS FORM CAN BE SAVED IN AN INCOMPLETE STATE AND RE-OPENED

Payback and implementation costs for improvements are requested when available.
Please indicate quanties with as much accuracy as possible.
Costs are relative to total capital improvements that year.

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SECTION I: Background Information. Please note if information is not available with n/a.

Airport Name _____

LocID _____ **City** _____ **State** Alabama

Terminal Square Footage - approximate _____

Primary Contact

Name _____ **Title** _____

Phone _____ **Email** _____

Person Completing the Survey if different

Name _____ **Title** _____

Phone _____ **Email** _____

First Page	**Previous Page**	**Next Page**	Last Page

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SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION II: Planning Practices. The following questions relate to planning for energy efficiency improvements at your facility. Check all that apply.

S2-1 How is the airport planning for future energy efficiency projects?

- ◯ Included in airport long range plan
- ◯ Energy audits with local utility
- ◯ Staff survey
- ◯ Ongoing Operations and Maintenance plan
- ◯ Other

S2-2 When considering facility or tenant/lessee improvements, does your airport rely on or implement design or performance standards to increase energy efficiency ?

- ◯ Tenant Design Standards
- ◯ Facility Design Standards
- ◯ No Standards
- ◯ Other

S2-3 Do design standards identified in the previous question apply to any or all of the following categories below?

- ◯ Lighting
- ◯ Plumbing Fixtures
- ◯ Metering
- ◯ Heating
- ◯ Cooling
- ◯ Ventilation
- ◯ Materials
- ◯ Other

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

S2-4 How does the airport identify energy efficiency projects?

- ◯ Utility Audits
- ◯ Commissioning
- ◯ Staff Survey
- ◯ Operations and Maintenance Monitoring
- ◯ Other

S2-5 What areas of planning for the airport include energy efficiency as a component?

- ◯ Long Range Airport Plan
- ◯ General Budget
- ◯ City / County Policy
- ◯ Other

S2-6 What actions within the budget process have allowed successful planning for energy efficiencyimprovements?

- ◯ Phased Funding
- ◯ Departmental Prioritization
- ◯ Other

S2-7 What documents or resources have been referenced when planning for energy efficiency improvements?

- ◯ Trade Publications
- ◯ Partner Agencies
- ◯ Other Airport Facilties Managers
- ◯ NAS Transportation Research Board ACRP Synthesis Documents
- ◯ Other

S2-8 Identify resources that have allowed for study and planning for energy efficiency improvements?

- ◯ Local Utility Grant
- ◯ Federal Grant
- ◯ Budgeting Line
- ◯ Other

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION III: Energy Efficiency Practices - Mechanical Systems. The following questions relate to mechanical systems at your facility and practices affecting energy efficiency that have been implemented or are planned at your facility . Check all that apply.

S3-1 Cooling - Identify new or upgraded cooling systems (check all types) ?

- ◯ central chiller plant
- ◯ rooftop air-handlers and/or split systems
- ◯ water-to-air heat pumps
- ◯ ground source heat pumps
- ◯ packaged air-conditioner (through-wall, window, etc.)
- ◯ well water usage
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S3-2 Winter Cooling - Is there any winter cooling utilized in your facility?

- ◯ Yes - central system capability
- ◯ Yes - local capability (computer room cooling, etc.)
- ◯ No

S3-3 Heating: Identify existing heating fuels (check all types)?

Primary Heating Fuel ☐ natural gas ☐ propane ☐ electric

Secondary Heating Fuel ☐ natural gas ☐ propane ☐ electric

◯ Other

S3-4 Solar Heating - Identify solar heating systems?

- ◯ hydronic panel collectors
- ◯ passive solar system (thermal mass, trombe wall, movable insulation, etc)
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS
ACRP SYNTHESIS S10-04
Airport Energy Efficiency and Cost Reduction

S3-5 Heating: Identify new or upgraded hydronic heating systems?

- ◯ central boiler plant feeding a heating water piping system
- ◯ central boiler plant feeding a steam piping system
- ◯ decentralized boiler
- ◯ water-to-air heat pumps
- ◯ ground-source heat pumps
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S3-6 Heating: Identify new or upgraded radiation heating systems?

- ◯ fin tube radiation heating
- ◯ radiant floor heat
- ◯ steam or hot water unit heaters
- ◯ rooftop air-handlers with gas-fired furnaces
- ◯ electric heat - unit heaters, duct coils, fin tube, floor heat
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S3-7 Heating: Identify new or upgraded heat recovery systems?

- ◯ boiler stack
- ◯ chiller or heat pump (cooling one space helps to heat another)
- ◯ cogeneration (electrical generator heat recovery)
- ◯ building exhaust ☐ pump around loop ☐ energy wheel - dessicant ☐ air-to-air
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS
ACRP SYNTHESIS S10-04
Airport Energy Efficiency and Cost Reduction

S3-8 Are motor controls used to save energy?

- ◯ variable speed fans
- ◯ constant speed fans with throttling discharge dampers
- ◯ constant airflow systems - no need to control airflow
- ◯ cooling tower fans
- ◯ variable or constant speed pumps
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S3-9 Has thermal storage been used to reduce energy costs?

- ◯ ice storage to shift the cooling load off-peak
- ◯ chilled water storage to shift the cooling load off-peak
- ◯ ground source heat pump / geothermal
- ◯ other
- ◯ none

S3-10 Has the airport implemented troubleshooting strategies, efficiency standards or other on-going engineering programs to improve energy efficiency?

- ◯ commissioning new projects
- ◯ periodic recommissioning of existing systems
- ◯ project energy efficiency standards such as LEED or state/local standards
- ◯ energy audits and/or professional energy studies
- ◯ on-going energy conservation program with annual investment
- ◯ payback or ROI criteria for investements that improve energy efficiency
- ◯ other

S3-11 Has the airport implemented building automation strategies that have reduced energy consumption?

- ◯ yes
- ◯ no building automation
- ◯ specify

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION IV: Energy Efficiency Practices - Electrical Systems. The following questions relate to electrical systems at your facility and practices affecting energy efficiency that have been implemented or are planned at your facility . Check all that apply.

S4-1 What types of lighting controls are used and have savings been documented.

- ◯ timeclock
- ◯ daylight harvesting with photocells and dimming control
- ◯ occupancy sensors
- ◯ timer switches
- ◯ centeral lighting control system
- ◯ multi-level switching

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S4-2 If the airport terminal has pursued lighting retrofit programs, what was the conversion?

- ◯ old fluorescent to T8 fluorescent
- ◯ incandescent to fluorescent
- ◯ incandescent to HID
- ◯ incandescent to LED
- ◯ fluorescent to LED
- ◯ HID to fluorescent
- ◯ HID to LED
- ◯ HID to fluorescent
- ◯ magnetic ballasts to electronic ballasts
- ◯ lower wattage energy saving lamps
- ◯ none

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

S4-3 Does the airport have a regular program of light fixture and/or lamp replacement?

- ◯ yes
- ◯ no

S4-4 Has the airport reduced electrical costs with metering or rate adjustments?

- ◯ no
- ◯ yes

S4-5 Please identify existing electrical metering configuration?

Metering: Service Meters Only

◯ other:

S4-6 Please identify existing electrical rate arrangement?

Rates: Primary (customer owned transformer)

◯ other:

S4-7 Has the airport implemented power factor correction to reduce electrical costs?

- ◯ yes
- ◯ no

S4-8 Has the airport replaced flight, baggage or other infomation displays to reduce electrical costs? If so, please identify current displays used.

- ◯ CRT's
- ◯ LED's
- ◯ LCD's
- ◯ Plasma

S4-9 Does the airport control baggage or other infomation displays to reduce electrical costs? If so, please identify control type.

- ◯ none / manual
- ◯ occupancy sensor
- ◯ timeclock
- ◯ automated control system

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

S4-10 Does the airport control illuminated signage to reduce electrical costs? If so, please identify control type.

- ◯ none / manual
- ◯ occupancy sensor
- ◯ timeclock
- ◯ automated control system
- ◯ photocell

S4-11 Has the airport installed energy saving features to conveyance systems? If so, please identify control type?

- ◯ none
- ◯ speed controllers (elevators and trams)
- ◯ NOLA devices (escalators and moving walks)
- ◯ variable frequency drives or adjustable frequency drives (baggage conveyors)
- ◯ photocell

S4-12 What types of alternative energy production are utilized to provide power?

- ◯ purchase of carbon credits
- ◯ purchase of "green power" from utility
- ◯ on-site photovoltaic array - grid tied
- ◯ on-site photovoltaic array -
- ◯ on-site wind turbine(s)
- ◯ hydroelectric
- ◯ biomass fueled generator

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION V: Energy Efficiency Practices - Building Envelope. The following questions relate to the building envelope and practices affecting energy efficiency that have been implemented or are planned at your facility . Check all that apply.

S5-1 Identify projects related to building insulation and air infiltration that have resulted in energy savings?

- ◯ none
- ◯ roofing insulation exceeding code minimums at re-roof
- ◯ super-insulation on new projects
- ◯ air leakage detection and reduction - gap filling

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S5-2 Identify projects related to glass and glazing that have resulted in energy savings?

- ◯ none
- ◯ glass - window replacement with high performance, insululated, low-e or other
- ◯ glass - retrofit with solar control film
- ◯ interior shading devices (automatic operation)
- ◯ interior shading devices (manual operation)

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S5-3 Identify any retrofit daylighting systems that have measurably reduced energy costs?

- ◯ none
- ◯ skylights
- ◯ light tubes
- ◯ sunlight collector with fiber optic distribution (Parans System)
- ◯ interior light shelves
- ◯ exterior shading devices - awnings, louvers, other

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

S5-4 Identify any retrofit door, entry and exit systems that have measurably reduced energy costs?

- ◯ none
- ◯ man-doors - replacement with automatic, self-closing or other
- ◯ man-doors - replacement of weather seals, closers, other
- ◯ roll-up doors - replacement with automatic, self-closing or other
- ◯ roll-up doors - replacement with insulated
- ◯ other

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

NEXT SECTION CONTINUES ON NEXT PAGE

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION VI: Energy Efficiency Practices - Operations. The following questions relate to the practices affecting energy efficiency that have been implemented or are planned at your facility . Check all that apply.

S6-1 Identify any projects related to office systems that have measurably reduced energy costs?

- ◯ none
- ◯ replacement and upgrade of monitors and displays (CRT to LED)
- ◯ staff workstation nightly shut-down
- ◯ other

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S6-2 Identify any projects related to occupant behavior that have measurably reduced energy costs?

- ◯ none
- ◯ training programs
- ◯ mandated staff work practices
- ◯ other / additional info

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S6-3 Identify operational practices that have measurably reduced energy costs?

- ◯ none
- ◯ troutine maintenance
- ◯ tenant mix
- ◯ lease arrangements
- ◯ other / additional info

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

S6-4 Identify operational arrangements that have affected the airports ability to control or implement energy efficiency strategies?

- ◯ none
- ◯ tenant lease terms
- ◯ maintenance agreements
- ◯ other

$ **Estimated Payback** ☐ 0-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10 + years

$ **Cost to Implement** ☐ no-cost ☐ low-cost ☐ med. cost ☐ high cost

S6-5 In what ways has the airport changed operations in order to implement energy efficiency measures ?

- ◯ none
- ◯ please specify

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

SECTION VII: Energy Efficiency Practices - Implementation. The following questions relate to implementation of energy efficiency practices at your facility .

S7-1 What type of energy efficiency improvement brings the most rapic payback for the least cost?

- ◯ operations
- ◯ mechanical systems
- ◯ electrical systems
- ◯ building envelope
- ◯ operations
- ◯ other

S7-2 How have energy efficiency improvements been funded ?

- ◯ line item in budget
- ◯ FAA / AIP
- ◯ FAA Special Grant (VALE or other)
- ◯ State DOT
- ◯ Local Authority
- ◯ State Utility Grants
- ◯ other

S7-3 What factors aid in implementation of energy efficiency projects?

- ◯ funding source outside regular budget
- ◯ policy change by governing body
- ◯ staff behavior
- ◯ technical / design
- ◯ political
- ◯ other

SURVEY QUESTIONNAIRE FOR AIRPORTS
ACRP SYNTHESIS S10-04
Airport Energy Efficiency and Cost Reduction

S7-4 Does your facility have a dedicated energy manager ?

- ◯ yes
- ◯ no
- ◯ other

S7-5 What types of resources were used to support and justify energy efficiency projects?

- ◯ payback from past projects
- ◯ literature / case study
- ◯ NAS synthesis / industry reports
- ◯ commissioning or energy audit
- ◯ other

S7-6 What types of challenges impede implementation of energy efficiency projects?

- ◯ funding
- ◯ policy
- ◯ technical issues
- ◯ operational control setup
- ◯ other

S7-7 How would you categorize the impact of energy efficiency projects implemented at your airport in terms of energy cost savings?

- ◯ low - not quantifiable
- ◯ medium - noticable
- ◯ high - "big bang", major change and cost savings
- ◯ comments

SURVEY QUESTIONNAIRE FOR AIRPORTS
ACRP SYNTHESIS S10-04
Airport Energy Efficiency and Cost Reduction

S7-8 If funding for facilility improvements was available, please rank which area of savings would be your top priority?

- ◯ yearly energy cost reduction
- ◯ reduced maintenance of systems (i.e. relamping)
- ◯ improved passenger, tenant, staff comfort
- ◯ improved controllability of systems
- ◯ woudl not spend on energy efficiency
- ◯ other

S7-9 What categories of information woudl be most useful to airport facilities managers and staff to plan for and implement energy efficiency improvements?

- ◯ Return-On-Investment (ROI) chart for typical energy efficiency improvements
- ◯ Cost based chart comparing typical energy efficiency improvements
- ◯ implementation strategies chart for typical energy efficiency improvements
- ◯ all of the above
- ◯ other

S7-10 Please use this space to provide any additional comments regarding airport terminal energy efficiency that you feel would be helpful to the study?

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100% SURVEY COMPLETE

SURVEY QUESTIONNAIRE FOR AIRPORTS

ACRP SYNTHESIS S10-04

Airport Energy Efficiency and Cost Reduction

Thank you for your assistance in completing this questionnaire. Your responses will help provide insights into economic practices for improving airport terminal energy efficiency.

Please follow the directions below to print and transmit your responses to this survey.

NEXT STEPS:

Selected respondants will be contacted to discuss responses to the questionnaire and energy efficiency practices at your facility by the TRB Consultant. If you are interested in being contacted, and would like to share more infomation about energy efficiency practices - please check the box below.

◯ yes - please contact me to discuss energy efficiency practices

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APPENDIX C

List of Airports Responding to Survey

TABLE C1
AIRPORT ENERGY EFFICIENCY AND COST REDUCTION AIRPORT SURVEY RESPONDENTS
ACRP Project 11-03 / Topic S10-04

Rank	ST	Locid	City	Airport Name	CY2007 Enplanements	Survey Respondent
4	TX	DFW	Fort Worth	Dallas/Fort Worth International	28,482,417	Energy and Transportation
8	AZ	PHX	Phoenix	Phoenix Sky Harbor International	20,796,173	Environmental Coordinator
10	NJ	EWR	Newark	Newark Liberty International	18,163,652	Airport Facilities Manager
14	MN	MSP	Minneapolis	Minneapolis-St Paul International/Wold-	16,962,563	Construction Manager
26	FL	TPA	Tampa	Tampa International	9,306,036	Senior Director of Maintenance
33	MO	STL	St. Louis	Lambert-St Louis International	7,130,801	Electrical Engineer
43	PA	PIT	Pittsburgh	Pittsburgh International	4,875,883	Principal Architect for Airport Authority
63	NV	RNO	Reno	Reno/Tahoe International	2,450,451	Director of Facilities and Management
70	VA	RIC	Highland Springs	Richmond International	1,805,992	Director Real Estate & Facilities
105	VT	BTV	Burlington	Burlington International	703,186	Director of Planning & Development
108	CA	FAT	Fresno	Fresno Yosemite International	636,032	Airports Planning Manager
116	IA	CID	Cedar Rapids	The Eastern Iowa	530,417	Director of Operations
136	AK	JNU	Juneau	Juneau International	403,825	Airport Architect
160	FL	EYW	Key West	Key West International	270,781	Airport Director
163	MI	LAN	Lansing	Capital City	256,563	Development
185	AL	MGM	Montgomery	Montgomery Regional (Dannelly Field)	181,231	Airport Manager
335	MN	BJI	Bemidji	Bemidji Regional	22,302	Airport Manager
432	ND	DIK	Dickinson	Dickinson - Theodore Roosevelt Regional	7,603	Airport Manager
434	OR	PDT	Pendleton	Eastern Oregon Regional at Pendleton	7,541	Airport Manager
483	WV	PKB	Parkersburg	Mid-Ohio Valley Regional	4,531	Airport Manager

APPENDIX D

Energy Efficiency Practices and Payback Matrix

TABLE D1
ENERGY EFFICIENCY PRACTICES AND PAYBACK MATRIX

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[2,3]					PAYBACK[1]					%[4] Energy Savings	COMMENTS
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown		
AUTOMATION / CONTROLS														
Automation improves monitoring and and management of building systems.	BUILDING AUTOMATIONS SYSTEMS													
	BAS allows the building HVAC and lighting systems to react automatically to the operating environment, adjust to meet load conditions, and help schedule or identify equipment needing maintenance or adjustment.	**BAS Thermal Environment Calibration**		■				■					2%	
		Maintaining comfortable conditions can be a challenge for BAS and airport operators												ASHRAE 55-2004 can be used for new construction and retrofit programs to establish parameters for proposed HVAC systems and to evaluate existing thermal environments.
		BAS Sensor Optimization		■				■	■					
		without accurate sensor calibration, BAS can return inaccurate data potentially wasting energy, disrupting occupant comfort and causing unnecessary wear or replacement of system components.												Can offset challenges of aging mechanical equipment and legacy sensors.
		BAS Upgrade			■					■				
		can reduce off-line time for crucial equipment by detecting fluctuations in performance or degrading components and alerting operations and maintenance staff earlier												Without automation, energy efficiency improvements would not have been identified in the first place
	MOTOR CONTROLS													
	Heating and cooling systems with computer controls or variable frequency drives (VFDs) that sense real-time load or demand and automatically adjust to optimal efficiency	**Fans - Variable Speed Drives**		■				■	■					
		Application or replacement of variable frequency drive (VFD) controls to fans through a BAS												
		Pumps - Variable Speed Drives		■	■				■					
		Application or replacement of variable frequency drive (VFD) controls to chilled water pumps through a BAS												See Figure 2
		Fans - Cooling Tower		■	■				■					
		Retrofit of cooling tower fans with variable drive												
OPERATIONS AND MAINTENANCE														
O & M should be the first airport area studied for energy cost savings.	SYSTEMATIC EVALUATION													
	The evaluation and maintenance of existing systems is an accessible and effective method of improving energy efficiency.	**Energy Audits**		■				■						
		An evaluation of the energy used by existing equipment over a period of time.												Audits are often a project financing requirement that serves to provide assurance that the investment is financially sound.
		O & M Assessment		■	■			■	■					
		A way to identify low-cost changes in O&M practices that can improve building operations.												Assessement may aid in reducing the payback time for capital improvements identified in the energy audit because of low-cost operations improvements.
		Energy Assessment			■			■	■					
		Identify potentially beneficial equipment upgrades, needed equipment repairs, and beneficial changes in operating procedures												Energy assessment can represent the most objective opinion of what is needed to reduce costs and therefore be very useful in support of energy efficiency programs.
		Re-Commissioning / Optimization		■				■					5-15%	
		Re-Commissioning and optimization for existing buildings or systems will return those systems to design specifications while accommodate facility or tenant operating requirements.												Retro-commissioning can often return both energy efficiency savings and O&M improvements since they can be performed by staff and will raise awareness of energy savings potential.
		Basic Commissioning		■	■	■		■	■					
		Commissioning for a new building or system ensures that equipment is installed and operating properly												Commissioning should be initiated early in the design process to achieve the greatest benefit. See Figure 3 for information on equipment.
		Continuous Commissioning				■		■	■					
		Commissioning integrated into the day-to-day O&M program at a facility.												A specialized process that requires additional measurement
	SPECIAL PROGRAMS & OPERATIONAL ARRANGEMENTS													
	Use special programs to guide, implement and monitor energy efficiency projects.	**Maintenance Agreements**	■					■						
		Incentivize energy efficiency improvements through performance based service contracts.												Energy Service Companies or ESCos specialize in comprehensive programs.

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TABLE D1
(*continued*)

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[2,3]					PAYBACK[1]					%[4] Energy Savings	COMMENTS
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown		
		Preventive Maintenance Programs						■						
		The documentation of proceedures reduces dependence on individual specialized knowledge.												Seasonal review of programs is important.
		Temporary Settings / Mothballing		■				■						
		Shut-down or mothball non-essential systems and spaces to reduce energy use.												Utilize BAS to implement short term shut-downs.
		Energy Efficiency Specific Project Criteria		■	■									
		Utilization of existing programs or guidelines to guide energy efficiency projects.												Staff or consultant time is saved by not having to develop standards.
		Airport Wide Energy Sustainability Programs		■	■			■	■					
		Fostering a culture that supports energy efficiency will garner long term commitment to improvements from staff and airport users alike.												Essential in promoting a "culture of sustainability".
	PERSONNEL / HUMAN FACTORS													
	Personnel and their awareness and attitudes toward energy efficiency projects are an important part of implementation.	**The Hawthorne Effect**	■					■						
		Small improvements in efficiency can be expected when personnel are aware of the improvement or program.												
		Training		■										
		Utilize "energy awareness" training programs for staff and tenants to raise awareness about energy efficiency measures												Operations training for O&M staff and day-to-day users of airport equipment, from simple thermostats to energy management control systems is crucial to the successful utilization of those energy management tools.
		Communications		■				■						
		Information about energy cost-reduction practices must be distributed to personnel and stakeholders.												Designate space for energy efficiency information within staff common areas.
SOURCES														
Future energy sources that will reduce energy costs are largely based on solar power although in some parts of the country where biomass is available, cogeneration plants may also served to meet airport energy needs.	NON-RENEWABLE													
	As greater carbon controls put in place, airport terminals and other large commercial buildings will be affected by rising energy costs.	**Multiple Fuel Sources**												
		Additional fuel sources like fuel oil or jet fuel protect the airport from dramatic fluctuations in fuel cost and may reduce peak demand charges by allowing on-site energy generation.												Dependent on local availability.
	RENEWABLE													
	Solar and geothermal power hold promise for airports.	**Solar Photovoltaic**		■	■	■		■	■	■	■			
		The technology is still largely unable to compete with non-renewable power in most regions.												Estimated payback time for solar photovoltaic systems at airport terminals depends largely on where the airport is located and what rebates or incentives are provided by local utilities, state and federal governments.
	METERING ENERGY USE													
	Metering technologies allow airport operators to initiate best management practices, monitor trends in energy use and improve building operations.	**Service Meter Data Baseline**		■				■						
		Energy savings can be accurately estimated and precisely confirmed with baseline data.												Start with energy billing information.
		Advanced Meters		■				■						
		Advanced metering system gathers energy use data on a defined scheduled as well as on-demand, enabling real-time monitoring of electrical use, time-based rates and continuous commissioning.												System costs vary widely for a number of reasons: equipment specifications and capabilities, existing infrastructure, site-specific design conditions, local cost factors.

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TABLE D1
(*continued*)

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[2,3]					PAYBACK[1]					%[4] Energy Savings	COMMENTS
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown		
		Electronic Sub-Metering			■			■						
		Sub-meters determine energy use by multiple users, systems or tenants and add a finer grain to energy data.												Sub-meters allow accurate tracking of energy use and monitoring of energy efficiency improvements.
	ENERGY RATES													
	By understanding utility rate structures, incentive programs for reducing loads and penalties or peak demand charges, airport terminals are better prepared to manage energy use and reduce costs.	**Rate Adjustment with Advanced or Sub-Meters**		■										
		Most rate-based programs work to incentivize off-peak use of electricity and reduce peak load demand. Specific programs include time-of-use pricing, real-time pricing and load aggregation.												Advanced meters provide a greater understanding of unique airport terminal load characteristics, and a more knowledgeable position when negotiating rate-based programs.
		Peak Load Shedding						■						
		Energy at off-peak times is used to heat or cool a material (usually water) that is then utilized for heating or cooling energy during peak times.												Works best at facilities with large summer cooling loads. Requires a dedicated O&M staff and a favorable utility electric rate structure to be economically viable.
MECHANICAL HVAC														
Heating, Ventilation and Air Conditioning can consume around 40% of electrical energy at airports, with most of that being used by air condition systems.	HEATING - HYDRONIC													
	Retrofit of hydronic systems can improve efficiency by accurately sizing systems to meet heating demands.	**Solar Thermal**			■				■					
		Solar thermal systems consist of roof-mounted panels through which water or a glycol-water mixture passes to gain thermal energy.												Solar thermal can also be used to supplement boiler systems
		Central Boiler Upgrades		■	■	■		■	■	■	■			
		Boiler replacement brings greater efficiency, multiple fuel options and reduced maintenance costs.												Additional strategies may include replacing one boiler with multiple units, and the addition of direct digital controls to increase boiler efficiency.
	ENERGY RECOVERY SYSTEMS													
	Heat recovery units increase heating and cooling efficiency by capturing or "recovering" energy from exhaust air that would otherwise be lost.	**Plate and Frame (Fluid) Heat Exchangers**			■			■						
		High efficiency plate and frame heat changers transfer energy over a greater surface area than traditional fluid heat exchangers, greatly increasing the speed of the process.												Installation may be possible by airport staff.
		Air-to-air Heat Exchangers			■				■	■				
		Air –to-air systems use a film or plate over which the air passes to transfer energy between supply and exhaust airstreams.												Heat exchangers hold promise for many small airports, and should be considered as a component of mechanical retrofit.
	COOLING													
	When replacement occurs due to age, it is very likely that new systems will save energy simply because of improvements to the technology.	**Central Chiller**			■				■	■				
		Chillers and other components of the cooling system are often oversized or have become oversized due to reduced cooling loads generated by lighting retrofits.												If chiller size is deemed inadequate, improvement that reducing cooling loads may be less than the cost of additional chillers.
	PACKAGED HEATING AND COOLING													
	Many small airports utilize packaged mechanical systems.	**Rooftop Air-Handlers**			■				■					
		Improvements come from increased combustion efficiencies and from the ability to deliver conditioned air only were it is needed with VAV boxes.												
		Packaged Air-Conditioners			■				■					
		Replacement of older systems with more energy efficienct systems.												Data and communications rooms continue to increase in size and cooling demand due to more advanced building automation and communications.
		Economizer								■				
		Economizers can reduce energy required to meet cooling loads and can account for significant reductions in energy cost.												Unique conditions at airports may limit applicability for terminal buildings. Fuel and exhaust odors must be considered.

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TABLE D1
(*continued*)

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[2,3]					PAYBACK[1]					%[4] Energy Savings	COMMENTS
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown		
After Operational and Maintenance (O&M) improvements, lighting holds the greatest potential for energy savings at small airport terminals.	LAMP & FIXTURE RETROFIT													
	Lighting improvements are one of the most noticeable ways to save energy and, may elicit positive feedback from airport occupants and tenants.	**Upgrade to Flourescent Screw-type Bulbs**		■				■						
		Replacement of screw-type bulbs is often the easiest lighting upgrade to perform.												Maintenance savings may also be found due to longer life bulbs.
		Fluorescent Fixture Upgrade		■				■						
		Upgrading magnetic ballast fixtures to electronic ballast fixtures includes upgrading to T-8 or T-5 lamps.												One of the most cost effective lighting upgrades.
	CONTROLS & SENSORS													
	The unique geographic and operational considerations of each airport terminal as well as multiple types and manufacturers of lighting controls call for detailed study and planning for these improvements.	**Timer Lighting Controls**		■				■						
		Simple on or off controls used for terminal spaces that have predictable hours of use.												Controlling the time when light fixtures are on or off is one of the most basic methods of limiting energy consumed and saving operating costs.
		Bi-Level Switching		■										
		iring allows multiple lamps to be controlled within a single fixture to accommodate up to four distinct lighting levels												This practice holds potential for greater control of lighting if intelligent lighting controls are implemented in the future.
		Multi-Level Switching and Daylight Harvesting		■				■	■					
		With multi-level switching, lighting levels in areas such as gate-hold, ticketing and other areas with typically extensive windows are reduced by switching off lamps within fixtures, balancing artificial light with daylight and maintaining even lighting with all fixtures on.												This type of improvement requires more sophisticated controls and has greater applicability where BAS exists.
		Occupancy Sensors		■	■			■	■				20 - 75%	
		Utilized in a variety of spaces including toilets, storage closets, stairwells, hallways and other areas with limited use or unpredictable use patterns.												Occupancy sensors may extend the life of fluorescent lamps, thereby increasing the re-lamping interval and providing additional savings.
		Central Automated Lighting Control		■	■			■	■	■				
		Integrated with Building Automation Systems.												Some central controls can track total hours that lamps have been in service, supplying operations staff with useful information with which to schedule re-lamping programs.
ELECTRICAL LOADS														
Implementing controls that allow reductions in energy consumption based on loads or temporary shut-down during off hours can mitigate impacts of expanded systems.	VISUAL INFORMATION DISPLAYS													
	Used primarily for communication at airports, often in large banks making up composite displays. Also used for staff computers and entertainment or advertising.	**Display Shutdown**												
		Manual or automatic shutdown of displays throughout office and public spaces when areas are not in use.												Displays on staff and tenant workstations should be shut down or placed in sleep mode during off hours. Visual information displays for baggage systems can be shut down between flights. Manual shutdown is typical at most airports surveyed. BAS can be utilized for FIDS and baggage displays
		Display Retrofit		■				■	■	■	■			
		Flat panel or LCD displays have been found to use up to 50% less energy than CRTs and generate less heat, thereby reducing cooling loads.												Literature sources found a longer payback of 11-13 years on replacement of CRT with LCD using 2005 costs.
	CONVEYANCE SYSTEMS													
		Baggage Conveyors, Escalators, Moving Walks											≤40%	
		Utilizing motor controls that are load sensitive, adjusting motors to meet demand, thereby reducing horsepower output and heat generated, which can extend the life of the motor and save energy.												Low friction belts for baggage systems can also improve efficiency.

(continued on next page)

TABLE D1
(*continued*)

SYSTEM	SUB-SYSTEM	ENERGY EFFICIENCY PRACTICE	COST[2,3]					PAYBACK[1]					%[4] Energy Savings	COMMENTS
			No	Low	Medium	High	Unknown	0-2	2-5	5-10	10+	Unknown		
BUILDING ENVELOPE														
One key aspect of energy efficiency on any building is preventing energy lost or gain through the exterior envelope.	MATERIALS													
	Building materials contribute indirectly to energy consumption at airport terminals by absorbing or reflecting the suns energy and increasing or decreasing cooling loads.	**Reflective Materials to Reduce Heat Gain**											≤ 50%	
		The primary materials strategy to reduce heat gain is to increase reflectance of the surface through installation of a light colored or white roofing.												The primary materials strategy to reduce heat gain is to increase reflectance of the surface through installation of a light colored or white roofing.
	GLAZING													
	Window glazing can managing the amount of heat that enters the building and reduce cooling loads.	**Films to Reduce Solar Gain**			■				■					
		Utilize films to block solar energy without reducing visibility.												Solar heat gain through windows and skylights can be a significant problem at airports built without high-performance, low emissivity coated glass.
	INSULATION													
	Increasing insulation in the exterior envelope of a building can reduce heating and cooling costs by reducing the energy loss to the exterior of the building. With large wall areas of glass in many airports, the primary surface that can benefit from added or improved insulation is the roof of the terminal.	**Roofing Retrofit**			■				■					
		Many airports utilize high performance low-slope roofs with long life spans. Building code requirements for roofing insulation have most likely changed since the last time a terminals roof was replaced and increasing insulation R-Values may be required.												Roofing replacement cost for buildings the size of airport terminals can be significant and varied due to a wide range of factors, however extra insulation can often be added with little difficulty.
		Super-Insulation			■			■	■					
		One insulation strategy for increased energy efficiency is to provide greater levels of insulation than required by building codes. Called "super insulation", R-Values are often doubled typical specifications for that region. This strategy serves to buffer the building from outside temperature swings and maintain interior temperatures for a longer period of time.												Utilized by Juneau International Airport.
	AIR MOVEMENT													
	Reducing outside air infiltration into the building by improving building envelope tightness is usually quite feasible.	**Reducing Infiltration & Loss**			■				■					
		Survey roof and wall penetrations and plug leaks.												Monitor installation of new equipment to ensure new leaks are not created.
		Controlling Doors and Openings			■			■	■					
		Utilize high speed or automatic doors to reduce opening time and energy loss.												

Notes:

1. Payback – time indicated refers to years required for improvement to return cost savings equivalent to project costs.
2. Cost information is based on energy rates for 2009 at respondent airport locations.
3. Cost can be defined as total project cost and not cost per square foot.
4. Percentage - value given represents a yearly reduction in energy or operations costs for that system or process.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation