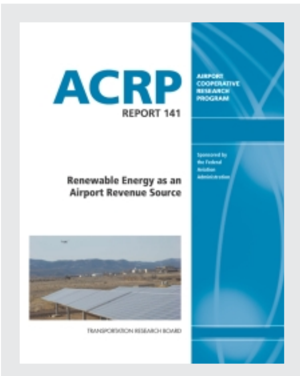


Renewable Energy as an Airport Revenue Source

DETAILS

212 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-30884-7 | DOI 10.17226/22139

AUTHORS

Whiteman, Adam; Bannard, David; Smalinsky, Terri; Korovesi, Iris; Plante, Jake; and Travis DeVault

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 141

Renewable Energy as an Airport Revenue Source

Stephen B. Barrett
Philip M. DeVita
HMMH
Burlington, MA

IN ASSOCIATION WITH

Adam Whiteman
Frasca & Associates, LLC
New York, NY

David Bannard
Foley & Lardner LLP
Boston, MA

Terri Smalinsky
Ziegler Investment Banking
Chicago, IL

Iris Korovesi
SunPower Corporation
Richmond, CA

Jake Plante
Plante Environmental LLC
Brunswick, ME

Travis DeVault
U.S. Department of Agriculture
Sandusky, OH

Subscriber Categories
Aviation • Energy • Finance

Research sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2015
www.TRB.org

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), Airlines for America (A4A), and the Airport Consultants Council (ACC) 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.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP REPORT 141

Project 01-24
ISSN 1935-9802
ISBN 978-0-309-30884-7
Library of Congress Control Number 2015944518

NOTICE

The project that is the subject of this report was a part of the Airport Cooperative Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the Airport Cooperative Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

Cover photo is of a solar PV project at Seneca County Airport in Tiflin, Ohio. Photo by David Bergman, U.S. Department of Agriculture, Wildlife Services Program.

Published reports of the

AIRPORT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Ralph J. Cicerone is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the National Academies of Sciences, Engineering, and Medicine to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org.**

C O O P E R A T I V E   R E S E A R C H   P R O G R A M S

CRP STAFF FOR ACRP REPORT 141

Christopher W. Jenks, *Director, Cooperative Research Programs*
Michael R. Salamone, *ACRP Manager*
Joseph D. Navarrete, *Senior Program Officer*
Terri Baker, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Margaret B. Hagood, *Editor*

ACRP PROJECT 01-24 PANEL

Field of Administration

Meenakshi Singh, *Norman Y. Mineta San Jose International Airport, San Jose, CA* (Chair)
Daniel P. Bartholomew, *Reno-Tahoe Airport Authority, Reno, NV*
Rhona DiCamillo, *DKMG Consulting, LLC, Wilmette, IL*
Jennifer M. Fuller, *North Carolina DOT, Raleigh, NC*
Robert A. Nicholas, *Ithaca Tompkins Regional Airport, Ithaca, NY*
William Shoard, *Energy Efficiency Group, New York, NY*
David Duchow, *FAA Liaison*
Aneil Patel, *Airports Council International - North America Liaison*
Christine Gerencher, *TRB Liaison*

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under ACRP Project 01-24 by HMMH.

Stephen B. Barrett, Director of Climate and Energy at HMMH, was Principal Investigator. The other authors of this report are Philip M. DeVita, Director of Air Quality, HMMH; Adam Whiteman, Managing Director, Frasca and Associates; David Bannard, Partner, Foley and Lardner LLP; Terri Smalinsky, Managing Director, Ziegler Investment Banking; Iris Korovesi, SunPower Corporation; Jake Plante, President, Plante Environmental LLC; and Travis DeVault, Field Station and Project Leader, USDA National Wildlife Center. Graphics prepared by Wanda Maldonado of HMMH. Maps prepared by Michael Hamilton of HMMH.

The authors would also like to thank the following individuals for contributing to the research.

Ameresco: Jim Walker; Cape & Vineyard Electric Cooperative: Liz Argo; Charlotte Airport: Patrick Cerri; Crawford, Murphy & Tilly: Brian Welker; Denver International Airport: Ed Keegan, Scott Morrissey; Duke Energy Renewables: Michael Butler, Iris Sandridge; Federal Aviation Administration: Patrick Magnotta; Grant County Regional Airport: Patrick Bentz; Halcyon Solar: Dan Herman, Josh Ebejer; Honeywell Corporation: Mike Janos, Max Lopp; Indianapolis Airport Authority: Tim Method; Johnson Melloh Solutions: Kurt Schneider; Lakeland Electric Company: Jeff Curry; Lakeland Linder Field: Brett Fay; Manchester Airport Group, UK: Adam Freeman; Massachusetts Port Authority: Terry Civic; Monterey Regional Airport: Mark Bautista, Chris Morello; Nantucket Memorial Airport: Noah Karberg; Outagamie County Airport: Scott Volberding; Portland Jetport: Paul Bradbury, Roy Williams, Anthony Newton; Redding Municipal Airport: Rod Dinger; Rural Renewable Energy Alliance: Roger Garton; San Diego County Regional Airport Authority: Ajay Babla; Shelby, North Carolina: Ben Yarboro, Jack Poole; The Minnesota Project: Fritz Ebinger; Tucson Airport Authority: Fred Brinker; University Park Airport: James Meyer; Volpe Center, U.S. Department of Transportation: Alexander Epstein; and HMMH: Kristine Collins, Crystale Wozniak.

FOREWORD

By Joseph D. Navarrete
Staff Officer
Transportation Research Board

ACRP Report 141: Renewable Energy as an Airport Revenue Source provides an overview of renewable energy in an airport setting; offers guidance for identifying, evaluating, and selecting financially beneficial renewable energy projects given an airport's unique characteristics; and gives the steps needed for implementing and operating a renewable energy project. The guidebook also includes detailed financial information on the cost and performance of projects that have been implemented by airports. The guidebook will be a particularly valuable resource for airport practitioners seeking to explore the potential benefits of this non-traditional revenue source.

Airports have the goal of maintaining fee and rental structures that will make them as financially self-sustaining as possible. To accomplish this, airports are now exploring non-traditional revenue sources and cost-saving measures. At the same time, utility service providers have recently begun looking for opportunities to purchase energy generated from renewable sources to meet state, regional, and federal environmental and energy goals. Since airports often have available property and facilities to host and generate clean and renewable energy sources, there may be opportunities for them to generate revenue and achieve cost savings. Nevertheless, the use of renewable energy as a revenue source is a complex issue, requiring an understanding of emerging technologies, financing mechanisms, regulatory frameworks, and operational factors. There is limited guidance to help airports identify, evaluate, select, and successfully implement renewable energy projects for financial benefit. Research was needed to develop a guidebook and present evaluation tools to help airports understand the feasibility, opportunities, and challenges of renewable energy projects and their implementation for revenue generation.

The research, led by HMMH, began with a literature review that included cataloging U.S. renewable policy incentives and funding programs for airport projects as well as summarizing applicable safety and environmental regulatory requirements. The review also led to the selection of a set of 21 representative projects that illustrate how airports have utilized renewable energy. These projects represented a range of project types (e.g., solar, wind, biomass, geothermal), airport sizes (e.g., large air carrier, regional, general aviation), and locations (New England, Midwest, Northwest, Southwest, Southeast). Based on the research, the team prepared its guidance.

The guidebook addresses the key challenges airports will likely anticipate when considering renewable energy as a revenue source. These considerations include the airport's geography and terrain, infrastructure, real estate, energy costs, public policy, regulatory and compliance requirements, tax credits, sponsor assurances, ownership, impacts to navigation and safety, security, staffing issues, and many others. The guidebook then offers a step-by-step approach to implementing a renewable energy project that addresses stakeholder coordination, partnering, procurement, contracting, environmental review, permitting, and management. Summaries of the 21 renewable energy projects examined as part of the research are also included. The guidebook also includes appendices offering supplemental information, including a list of airport solar projects, a review of the potential opportunities associated with biofuel feedstock, a renewable energy funding matrix, an example of a state's renewable energy programs, and an example solar feasibility assessment. The reader may access sample requests for proposals by visiting the project's publication page at www.trb.org/Main/Blurbs/172634.aspx.

CONTENTS

SUMMARY

Renewable Energy as an Airport Revenue Source

Airports are constantly looking for alternative revenue streams to increase their competitiveness and grow their businesses. They also are exploring ways to use technology to run more efficiently and achieve meaningful cost savings that can be passed on to anchor tenants in the form of more competitive rates and charges. Airports are rich in land and buildings connected to regional infrastructure that provide cost-effective investment opportunities that will benefit the airport business well into the future.

Renewable energy has become mainstream as a result of technological advancement, market maturity, and public sector policy and investment with profound benefits to power markets. Renewable energy has diversified the sources of energy and decentralized the power generation network increasing competition, expanding infrastructure investments, and improving national energy security and reliability of the electrical grid. It has increased regional competition for emerging energy generation with states vying for the new business opportunities and markets. It has also demonstrated the viability of a future carbon free economy with the design of high performance buildings that use less energy and supply what is needed through renewable sources.

For the energy consumer, renewable energy has unique business and public policy value.

- It requires no fuel, which stabilizes long-term power prices providing economic and security benefits (with the exception of biomass, which requires a local fuel source).
- It provides on-site power giving the user more control over power supply.
- It avoids emissions providing local and regional benefits with anticipated future monetary value (with the exception of biomass, which has emissions but its carbon emission is considered to be net zero).
- It has broad public appeal and is seen as an investment in the future.

This ACRP guidebook focuses on the financial benefits of renewable energy to airports.

Chapter 1 introduces the renewable energy technologies that are most relevant for airports and the key players involved in a renewable energy project. Technologies discussed include solar photovoltaics (PV) and thermal, geothermal, wind, biomass, hydro, and fuel cells.

Chapter 2 describes the evaluation factors that the airport should consider when assessing renewable energy options including the geography and characteristics of the airport, the airport's cost of energy, public policy programs that help to fuel the renewable energy market, project ownership options, and regulatory and safety issues.

Chapter 3 guides the reader through the process of conducting a financial assessment for a renewable energy project, including the types of financial benefits available, understanding project costs and identifying potential funding sources, and an introduction to existing publicly available financial models used to evaluate the economic viability of specific renewable energy scenarios.

Chapter 4 reviews the key implementation steps for developing a renewable energy project including engaging stakeholders, procuring the services of knowledgeable energy partners, and obtaining regulatory approvals.

Chapter 5 presents case summaries of airport renewable energy projects including financial information and business structures with examples from all of the technologies that have been successfully developed at airports and are currently generating renewable energy. The case summaries prepared for this report and their fundamental characteristics are listed in Table S-1.

The guidebook also includes a number of other valuable resources including:

- A series of decision-making flow charts to illustrate how airports identify the available renewable energy resource for their location and the appropriate business structure to meet their needs (see Chapter 2),
- A list of all known airport solar projects in the United States (Appendix A) and a map showing projects that are 100 kW or greater (Figure 1-5),
- A primer on financial modeling tools used in the renewable energy industry including PVWatts for solar, and the evaluation process and cost benefit tool (EP&CBT) for assessing sustainability practices at airports which was a product of *ACRP Report 110* (see Section 3.6),
- An introduction to biofuel feedstock propagation as a future opportunity for land-rich airports (Appendix B),

Table S-1. Airport renewable energy case summaries.

	Airport	State/Country	Technology	Ownership
1	Barnstable (HYA)	MA	Solar PV	Third Party
2	Boston – Logan (BOS)	MA	Solar PV	Third Party
3	Boston – Logan (BOS)	MA	Wind	Airport
4	Brainerd Lakes (BRD)	MN	Solar Thermal	Airport
5	Burlington (BTV)	VT	Wind	Tenant
6	Chicago-Rockford (RFD)	IL	Solar PV	Third Party
7	Denver (DEN)	CO	Solar PV	Third Party
8	East Midlands (EMA)	United Kingdom	Wind	Airport
9	Grant County (JDA)	OR	Biomass	Airport
10	Indianapolis (IND)	IN	Solar PV	Third Party
11	Juneau (JNU)	AK	Geothermal	Airport
12	Lakeland (LAL)	FL	Solar PV	Third Party
13	Nantucket (ACK)	MA	Geothermal	Airport
14	Outagamie (ATW)	WI	Solar PV, Thermal, Geothermal	Airport
15	Portland (PWM)	ME	Geothermal	Airport
16	Redding CA (RDD)	CA	Solar PV	Airport
17	San Diego (SAN)	CA	Solar PV	Tenant
18	San Diego (SAN)	CA	Solar PV	Third Party
19	Toronto (YYZ)	Canada	Solar Thermal	Airport
20	Tucson (TUS)	AZ	Solar PV	Airport
21	University Park (UNV)	PA	Geothermal	Airport

- A detailed funding matrix (Appendix C),
- A case study of North Carolina to illustrate the importance of state policy in the renewable energy sector and how it has benefited airports (Appendix D),
- A solar feasibility study for Monterey Regional Airport (MRY) to show the specific elements considered when assessing technical and financial feasibility (Appendix E), and
- Sample request for proposals (RFPs) from airport renewable energy projects (Appendix F, which is located on the TRB website at: http://www.trb.org/Main/Blurbs/172634.aspx.

This guidebook is designed to be a stand-alone reference with links to other sources of material as needed. However, it also complements and can be used in conjunction with several other ACRP publications, notably:

- *ACRP Synthesis 19: Airport Revenue Diversification*
- *ACRP Legal Research Digest 7: Airport Governance and Ownership*
- *ACRP Synthesis 28: Investigating Safety Impacts of Energy Technologies on Airports and Aviation*
- *ACRP Report 108: Guidebook for Energy Facilities Compatibility with Airports and Airspace*
- *ACRP Report 110: Evaluating Impacts of Sustainability Practices on Airport Operations and Maintenance*

The predominant message from this report is that airports and renewable energy have a strong association given their long-term business interests and common values that are best exemplified for a variety of different types and sizes of airports in the Chapter 5 case summaries. If there is limited time to invest in reading this report, the reader should move directly to Chapter 5 to see what airports are actually achieving in the field of renewable energy today.

CHAPTER 1

Introduction to Renewable Energy in the Airport Environment

Airports are operating today in an ever changing environment influenced by an interconnected world economy. With the effects of the great recession lingering and air travel in the post-911 world more costly, airports are striving to provide services more efficiently and identify a competitive advantage. In particular, airports see an opportunity to more fully utilize their land and facility assets to diversify their revenue streams (*1*).

Yet, airports come in many forms from the large international metropolis to the rural transportation terminus and each has different needs and assets available. According to a recent Report to Congress on the National Plan of Integrated Airport Systems (NPIAS), there are 3,331 operating public use airports in the United States (65% of all airports in the country), that are eligible to receive funding under the FAA's Airport Improvement Program (AIP) (*2*). Given the wide differences in their character, individual airports will deploy their assets in strategic and diverse ways.

What these airports have in common is their function as distinct government units. (Ninety-eight percent of airports in the NPIAS are owned by public entities: 38% city, 25% regional, 17% county, and 9% multi-jurisdictional. Of those, state ownership accounts for 5% and unified port authorities account for 3%). (*3*) They all provide aviation services to customers and are subject to federal regulatory oversight from the FAA (*4*). As a result, they must operate like a business providing services and collecting fees, while implementing public policy objectives in their government jurisdiction. This guidebook focuses on a topic area that can potentially fulfill both responsibilities: renewable energy as a potential revenue source.

1.1 Problem Statement

The ACRP issued a problem statement in 2012 titled, "Renewable Energy as an Alternative Revenue Source." The research objective was predicated on two fundamental points:

(1) Airports need to diversify potential fee and rental structures including non-traditional revenue sources that will make them as financially self-sustaining as possible.
(2) Renewable energy markets are growing and diversifying, fueled by requirements that utilities purchase renewable energy to meet state, regional, and federal environmental and energy goals.

Given that airports have underutilized property that could host renewable energy facilities and many consume significant quantities of power that could be provided more cheaply through on-site renewable generation, opportunities exist for airports to gain financial benefits from renewable energy. Kramer in *ACRP Synthesis 19* describes how airports can use ancillary land uses, such as mineral extraction and renewable resources (*5*).

Airport renewable energy projects can be complex, requiring an understanding of emerging technologies, financing mechanisms, regulatory frameworks, and operational factors. The ACRP determined that guidance is needed to help airports understand the feasibility, opportunities, and challenges of renewable energy projects for financial benefit.

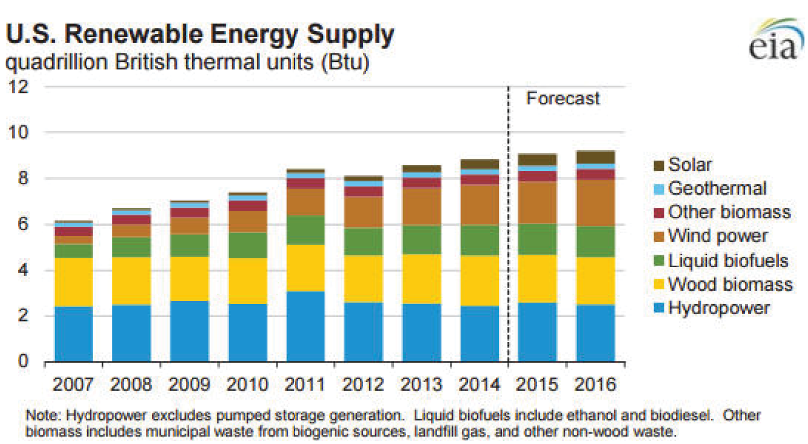
1.1.1 The Opportunity

Federal, state, and local governments have enacted renewable energy public policy to:

- Mitigate potential impacts of climate change;
- Increase the amount of domestic energy consumption;
- Diversify sources of energy;
- Invest in long-term savings associated with free renewable fuels;
- Decentralize power generation; and
- Stimulate job growth.

National investments in renewable energy have driven down solar panel production and installation costs, making solar electricity cost competitive with conventional sources. Similarly, utility-scale wind power constructed in large farms across the country represents more than a third of all new electricity generation over the past three years. New renewable-based fuels, like biogas and wood waste, are being produced in sufficient quantities to provide cost-effective fuel to fire conventional engines for electricity, heat, and mobile transportation. Newer technologies, like geothermal and fuel cells, are being successfully piloted through demonstration projects to show their commercial potential. Figure 1-1 shows the annual generation in renewable energy capacity over the past 8 years including the forecast out to 2016 as reported by the U.S. Energy Information Administration (EIA) (*6*). Policy incentive programs are envisioned to be temporary measures with sunset periods necessary to increase production and reduce costs to the point where renewable energy can be cost competitive with traditional sources. Solar and wind have approached a cost competitive level in some markets with solar power's federal investment tax credit (ITC) scaling back from 30% to 10% of project costs at the end of 2016 and wind power's production tax credit (PTC) having expired at the end of 2014.

The figure illustrates in particular the growth in wind power since 2009. Solar power has also shown a large increase over the past 5 years though the total amount of electricity being produced by solar still remains small compared to wind, liquid biofuels, wood biomass, and hydropower. The other renewable energy sources have remained relatively constant over the past 8 years with hydropower still the largest source of renewable energy. The EIA also forecasts that solar and wind will continue to increase in the future due to decreasing costs and available resources.



Source: Short-Term Energy Outlook, March 2015.

Figure 1-1. Renewable energy generation in the United States.

Airports have particular characteristics that enhance the potential financial viability of on-site renewable energy. Land and buildings can provide cost-effective physical locations for renewable energy facilities. The open landscape and geographic position of airports necessary for managing air traffic arrivals and departures also facilitates the capture of natural resources from the sun, wind, water, and earth that fuel renewable energy. Small rural airports may have surplus land available to site such facilities. Larger airports often have a level of electricity demand to support power consumption that positively affects project financials by avoiding the need to use the electrical grid. All of these attributes combined with improved renewable energy market conditions make airport renewable energy financially viable.

1.1.2 Guidebook Organization

The purpose of this guidebook is to provide airport readers with tangible information showing where renewable energy has produced a financial benefit in the form of an alternative revenue source or cost savings by limiting the need to purchase power from the grid. Through the examples, the reader can understand the factors that are considered by the airport in evaluating the renewable energy opportunity along with some of the financial benchmarks. While not all the cases are applicable to every airport, the types of information needed and the form that it comes in will be directly applicable. The airport case summaries are supported by additional guidance that will help airport decision-making of its own renewable energy opportunities, including which renewable energy resource is most appropriate given a particular airport's location, and what information is needed to begin an assessment of financial viability.

Chapter 1 provides an introduction to renewable energy at airports including description of technologies, the key participants in the airport renewable energy project, and the essential baseline information that the airport needs to consider renewable energy. Technologies summarized include solar PV and thermal, geothermal, wind, biomass, hydro, and fuel cells.

Chapter 2 presents the important evaluation factors that the airport should consider when assessing the renewable energy opportunity. These include setting of the project, airport characteristics, existing energy costs, relevant public policy programs, airport ownership options, regulatory requirements, and operational and safety considerations.

Chapter 3 examines in detail the financial factors that should be considered when evaluating whether or not a renewable energy project is anticipated to provide a financial benefit whether it be for revenue generation or cost savings. These include projected capital and maintenance costs, funding sources available to the airport, government incentive programs, preparing a cost-benefit analysis, and applying appropriate financial metrics such as the project return on investment or total cost of ownership.

Chapter 4 identifies the steps associated with implementing a project. These include coordinating with internal and external stakeholders, procuring and contracting with private partners, obtaining regulatory approvals, and publicizing the project milestones and accomplishments.

Chapter 5 presents case summaries of specific airport renewable energy projects to illustrate some of the concepts described above. These include a variety of airport sizes, regions of the country with a few international examples, renewable energy technologies, ownership models, and key participants.

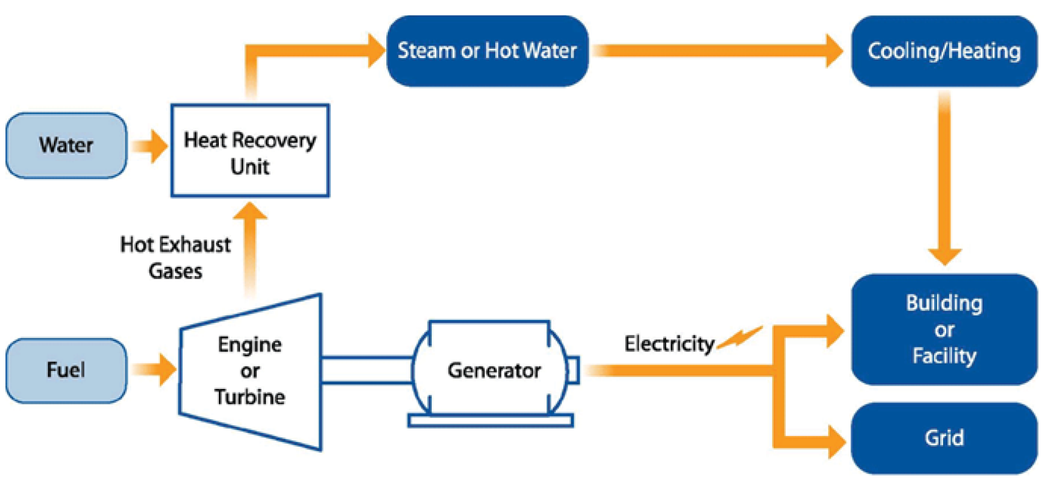
There are also a number of appendices and available resources. Appendix D is a summary of state renewable energy policies in North Carolina and airport solar projects that have been developed there to illustrate the importance of state policy incentives in project feasibility. Appendix E is a feasibility assessment for solar PV at Monterey Regional Airport (MRY) in California that provides readers with an up-to-date look at a current project example for California. Appendix F includes sample RFPs.

1.2 Renewable Energy Options for Airports

According to the EIA, renewable energy represents sources that are regenerative, inexhaustible, and can be sustained indefinitely. They are fueled either by energy resources that constantly occur in the environment, or by organic materials that are fast growing and potentially byproducts of other human processes. In comparison, conventional energy is customarily produced by burning fossil fuels such as coal and gas, which were formed deep in the earth over thousands of years and cannot be grown or manufactured. For centuries, renewable energy was the primary power source where wind was used to move ships and water to process grains. Burning fossil fuels was identified as a very efficient source of energy that helped drive the industrial revolution and has provided the energy needed for modern life. Centralized electricity plants fueled by fossil fuels were constructed to generate electricity and some incorporated co-generation technology to capture and use the waste heat (see Figure 1-2). Advances in new technologies to capture renewable energy ever more efficiently in the context of a planet warmed by extensive carbon emissions have triggered the recent trend back to renewable sources.

The amount of renewable electricity as a percentage of the country's total electricity generation has increased from 7.7% in 2000 to 12.87% in 2013 (*7*). Public policy incentives for renewable energy have opened up new opportunities for airports to obtain financial value.

Airports are always looking for opportunities to increase revenue to support their aviation businesses and improve their competitive position relative to each other. New energy development provides opportunity for both new revenue and cost savings. On the revenue side, airports may be able to lease land that is not useful for other aviation or non-aviation commercial



Source: US EPA, http://www.epa.gov/chp/basic/index.html

What is energy? Energy can be supplied in the form of electricity or heating/cooling. Renewable electricity generating technologies include solar PV, wind, and hydro. Heating/cooling can be fueled by electricity but may be more economical through thermal and combustion processes, which in the renewable sector is provided by solar thermal, geothermal, and biomass. Fuel cells generate electricity and heat. Co-generation systems produce both electricity and heating by capturing and utilizing waste heat. Combustion systems including biomass are best suited for co-generation.

Figure 1-2. Co-generation: electricity and heat.

business development, due to proximity and access to valuable airport infrastructure, earning potential revenue from those leases. For some airports, that means learning about the business and observing whether energy prices are high enough to justify investments based on revenue potential. Other airports may be interested in leasing land for solar PV installations. In terms of cost savings, airports may also consider developing solar or even wind energy if the production price is lower than existing electricity obligations to local utilities.

About three dozen solar projects have been developed at airports and business plans for their development have generally been of two types. First, airports can capitalize, own, and construct the facilities themselves, relying on low-interest bonds or federal government grants. The risk is held entirely by the airport but the benefits of free electricity will also be realized more immediately. The second option has been to lease land to a private developer of solar energy that can take advantage of federal and state tax credits (which are unavailable to public airports), the private developer then passes the financial benefits to the airport in the form of lease payments or discounted electricity. The sophistication and diversity in structuring energy projects has also increased the number of economically viable opportunities.

Units of Measure: Electricity is measured in watts. Electricity consumed is measured in watts per hour. Heat energy is expressed in Btus (British Thermal Units). To compare heat and electricity, watts can be converted to Btus (1 kilowatt hour = 3,412 Btus [as of 2013]) (see Figure 1-1). (*8*)

The following section provides a brief introduction to renewable energy technologies that may be viable options for airports and includes airport participation in these markets to date.

1.2.1 Solar

The sun's energy can be converted into useful forms of electricity and heat. PV technology turns light into electricity (*9*). The heat of the sun can also be concentrated on water and other fluids to produce steam generated electricity and provide direct heating (known as solar thermal). Most applications of solar have been to generate on-site power to homes and businesses. However, technology advances and recent market demands have led to an increase in utility scale electricity generation from large PV farms and concentrating solar power (CSP) plants which produce steam to drive a turbine.

The solar energy industry has expanded in recent years due primarily to reduced module production costs that have made solar technologies more affordable for utilities and consumers alike. In addition, the widespread deployment of solar technologies has been recognized by homeowners, businesses, and government agencies as a rational economic investment to minimize the risk from volatile energy prices in the future. For example, when a homeowner installs a system on his roof, he has a high level of certainty (usually warranted by manufacturers) about how much electricity the system will produce over a 25-year period. These factors have led to widespread adoption of solar and market confidence to sustain the industry into the future, irrespective of any future breakthroughs in efficiency gains that may be achieved.

Airports have also been an active participant in utilizing solar power primarily driven by the opportunities associated with decreasing installation prices. In most cases, the power generated by solar, primarily through PV along with a few solar thermal applications, is consumed at the

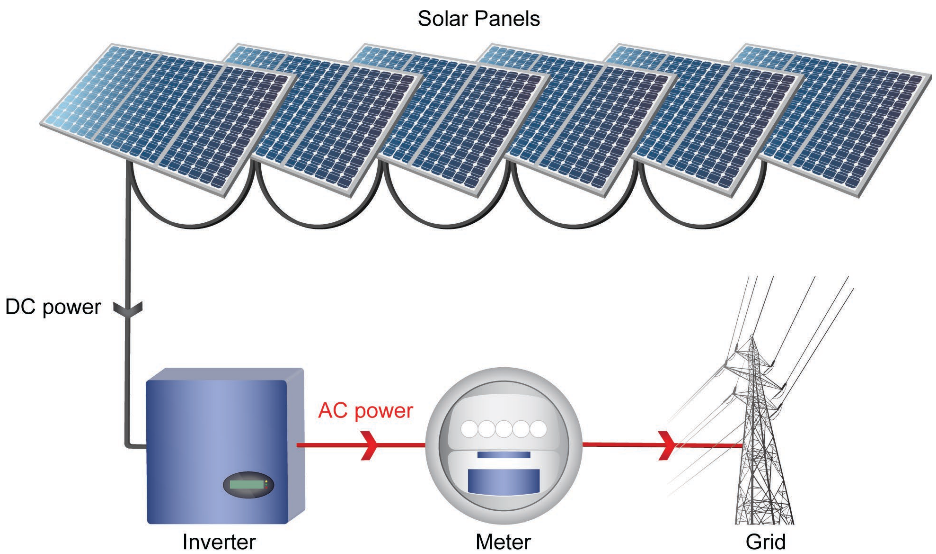


Figure 1-3. Schematic of a solar photovoltaic string.

airport. CSP is not practical for airport applications due to the need for large areas to locate mirrors and the incompatibility of the 400-foot plus tall power tower which collects the heat.

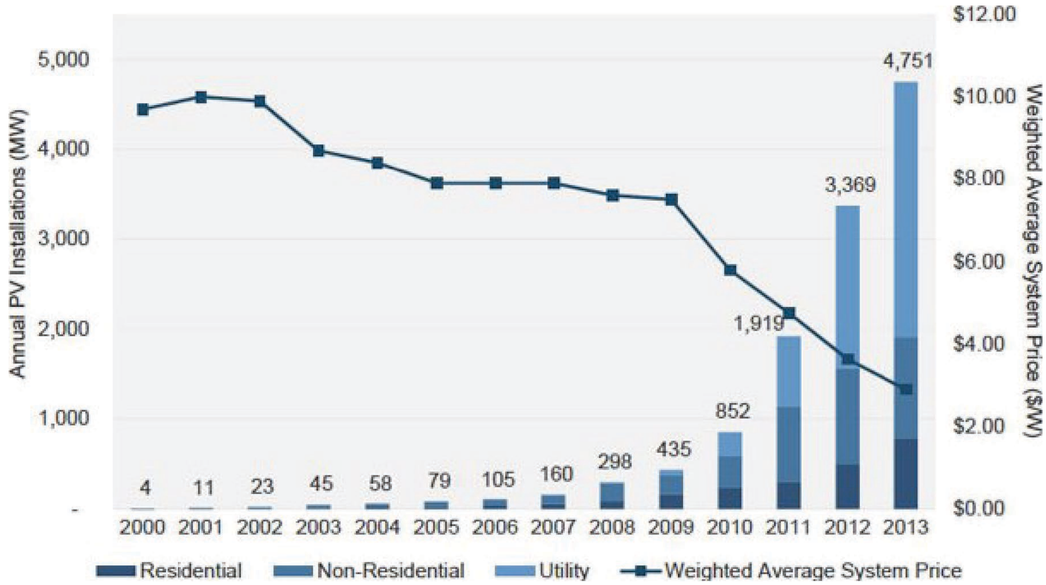
The partnership between airports and solar energy is a logical one given their open landscapes, the availability of large surfaces on buildings and open land to site projects, and the proximity to high-load electricity transmission infrastructure that airports provide. Airport managers have also recognized the business advantages of solar power as a source of alternative revenue and long-term cost savings. In addition, public policy benefits to the state, county, and municipal government agencies that manage public airports offer a purposeful basis for these projects, including the opportunity to achieve goals related to greenhouse gas reduction.

1.2.1.1 Photovoltaic

Solar PV is the direct conversion of sunlight into electricity. PV technology is constructed on flat panels that are located to optimize exposure to the sun (see Figure 1-3). The electricity produced is delivered in direct current (DC) form to an inverter which converts it to alternating current (AC) so that it can be compatible with the electrical grid and utilized by end users. The amount of electricity generated by the PV panel will vary with geography and the amount and intensity of sunlight available.

A strong advantage of solar PV is its flexibility in siting. The panels can be located on rooftops thereby avoiding the need to set aside land that may be valuable for other uses. Or the panels can be mounted on poles driven into the ground to form larger solar farms. Many roof and ground mounted panels are held in a fixed position but in other cases tracking mechanisms may be employed for ground-mounted systems to increase the efficiency of electricity generation. The low profile of solar panels either mounted on buildings or on the ground makes them less visible and may expand the areas where they can be located.

DC vs. AC: DC is the form of electricity produced by electrochemical and photovoltaic cells and batteries. The electricity delivered to homes and business by the utility is in the form of AC. An inverter converts power from a solar system from DC to AC. The conversion results in a loss of a small percentage of the power.



Source: Solar Energy Industries Association

Figure 1-4. Solar installations and system price over time.

The deployment of solar power has expanded throughout the United States over the past 5 years. Annual solar installations in 2013 were 15 times greater than installations in 2008 (see Figure 1-4). Decreasing costs of solar electricity have driven this growth with the installed cost of solar installations falling from $7.50/watt in 2009 to $2.89/watt in 2013 (*10*). The cost of solar panels fell by 60% from 2010 to 2012. In addition to lower solar costs, a variety of incentives are also creating a burgeoning solar market, including tax credits, purchasing mandates by federal agencies, and state level renewable energy portfolio standards. The amount of electricity produced by solar in the United States is now enough to power 1.3 million homes.

There has been widespread adoption of solar PV by airports throughout the world. This activity has been driven by the expanding solar PV market and associated financial benefits to airports from lease payments and electricity price stabilization over the term of a long-term contract. In

System Size: The size of solar, wind, and other electricity generating systems is expressed as a nameplate capacity. For solar PV, each solar panel has a nameplate of between 250 and 300 watts. Multiply the panel rating by the number of panels and you get the nameplate capacity of the facility. For wind power, there are varying turbine models with different generating capacities from 1 kW to 3 MW.

The nameplate capacity, if not otherwise specified, typically reflects the DC rating. Actual power available is the AC rating which is about 10% less. Also, the nameplate value is the maximum amount of electricity that will be generated at any single time when conditions are optimal. A capacity factor must also be applied to calculate the actual amount of electricity that will be generated by the system in kilowatt hours on average over the course of a year. For solar, capacity factor varies based on geography and technology, but is typically between 10 and 20%. For wind, it also varies by location but projects typically need a minimum of a 25% capacity factor. Offshore wind projects can have capacity factors of 50% or more.

addition, airports are regularly seeking to make their operations more sustainable, which has been an important but supplementary benefit. Furthermore, the flexible options in siting solar have provided airports with various options to consider a solar project that meets the scale and needs of an individual facility. Figure 1-5 shows airports in the United States that host a 100-kilowatt (kW) or greater solar PV system. A list of solar projects at airports is provided in Appendix A. Chapter 5 provides case summaries of solar PV projects exhibiting a variety of airport types and locations at Barnstable, Boston-Logan, Denver, Indianapolis, Lakeland, Redding, Rockford, San Diego, and Tucson including details on siting, ownership and financing. Several solar PV projects at airports are also described in the context of state renewable energy policy (see Appendix D for an example from North Carolina).

1.2.1.2 Thermal

Solar thermal technology stores and concentrates the heat of the sun for space heating (and cooling) and uses requiring hot water (see Figure 1-6). The energy from the sun is collected, stored, and distributed in liquid (usually water) or gas (air) form. There are low (less than 110°F) and medium (110° to 180°) temperature systems that can be used for on-site uses. High temperature systems are primarily used for utility-scale electricity generation. The number of low

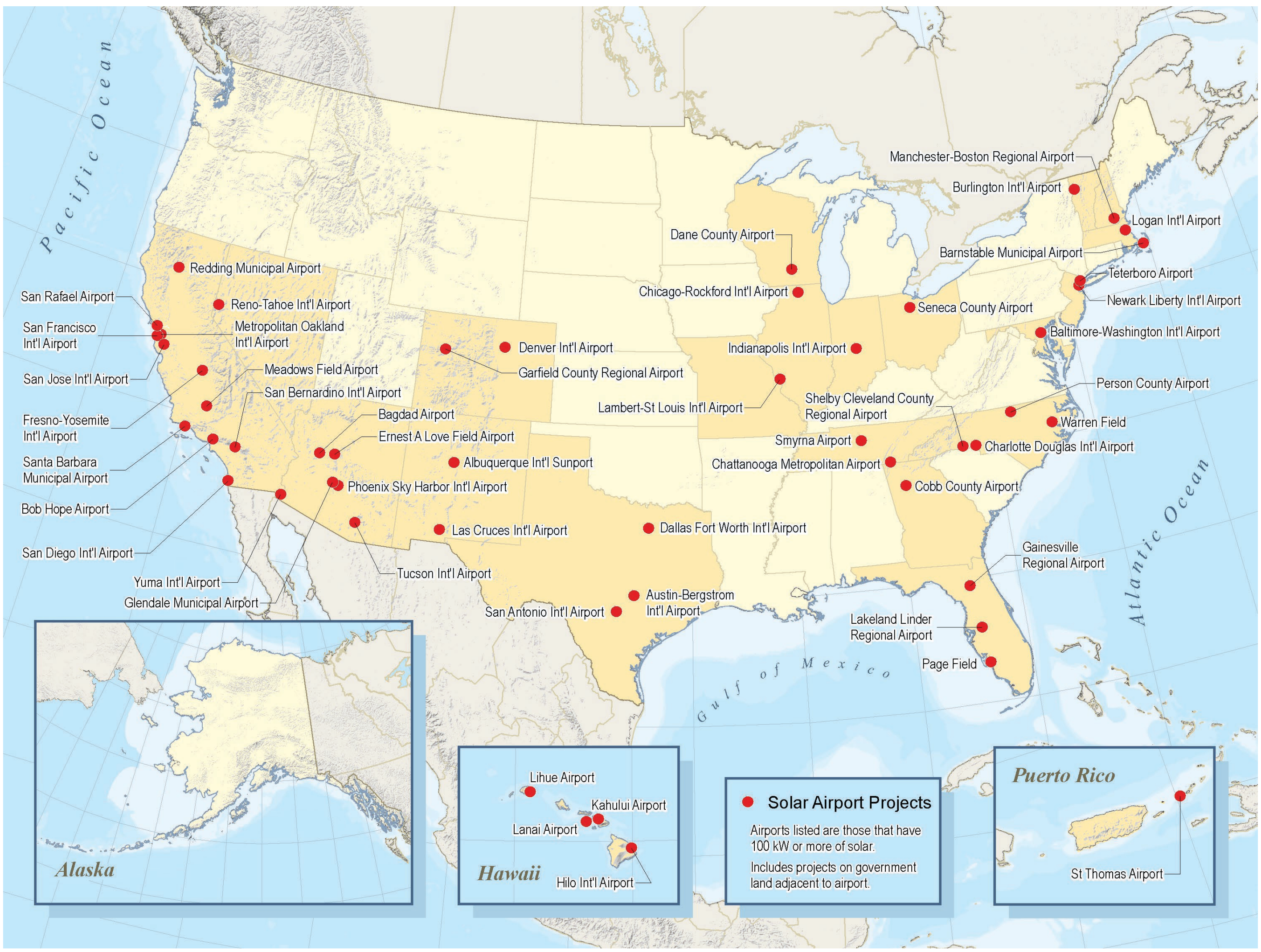


Figure 1-5. Solar PV facilities at airports in the United States.

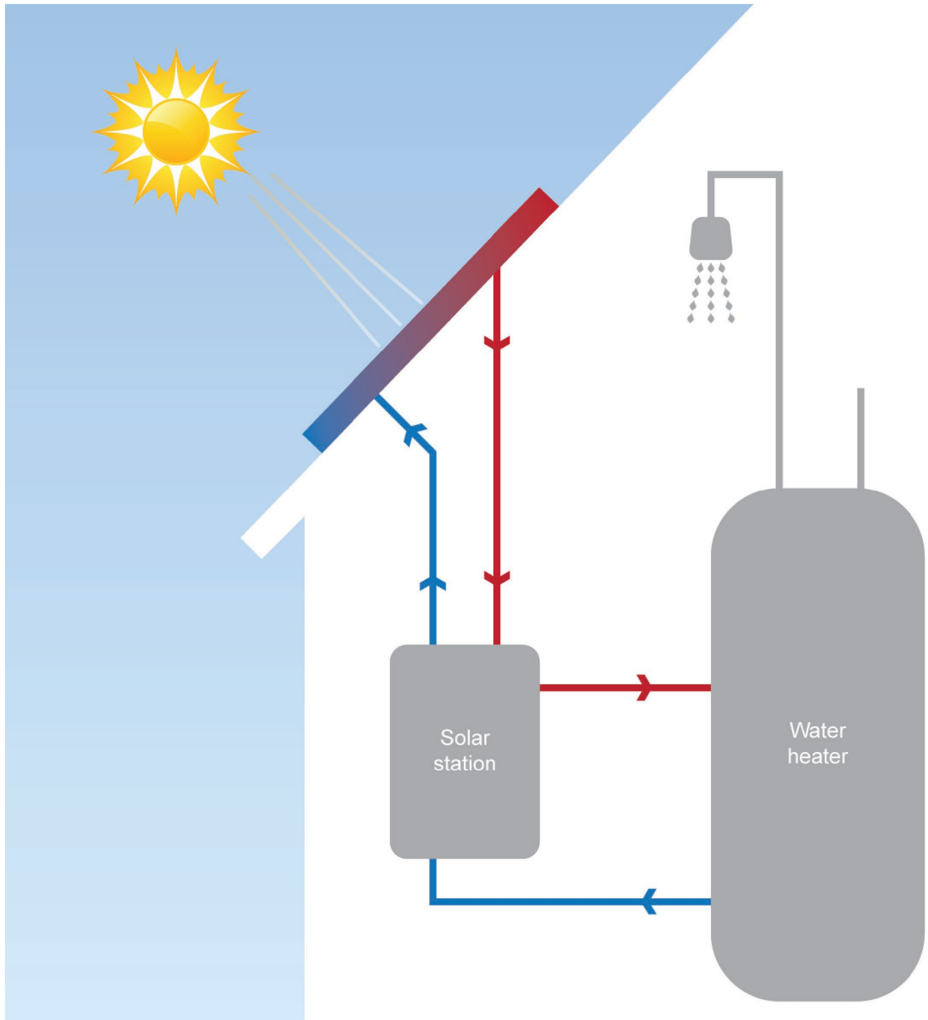


Figure 1-6. Schematic of a solar thermal system.

temperature collectors increased in the 2000s but by 2009 had dropped back to year 2000 levels (*11*). Medium size collectors have increased three-fold over the past 5 years but are only a fifth of what they were in the early 1980s. In 2009, three quarters of all collectors were low temperature models with 85% for residential use and 70% of all collectors were used for pool heating. The EIA projects solar thermal production to have an annual growth rate of about 2% over the next several decades compared to a 7% rate for solar PV (*12*).

Solar thermal collectors applicable to on-site heating and cooling have similar siting advantages as those described for PV. Thermal collectors are generally co-located with buildings, either on the roof or on south facing walls, to provide heating and cooling for internal operations. They have been particularly useful where low temperature hot water is used for heating and domestic uses as illustrated by the EIA statistics.

Solar thermal has had a more limited applicability for airports for a few reasons. One of the primary public policy incentives—the requirement that utilities purchase renewable electricity through a renewable portfolio standard (RPS)—is typically not applicable to renewable thermal energy. In addition, it can be difficult to retrofit existing heating and cooling systems with solar thermal and other forms of renewable thermal technologies (see geothermal). The best applications can be included in the design of new construction and particularly for designs seeking a zero carbon result whereby solar thermal can provide a benefit to reduce carbon emissions from heating and cooling. Despite these barriers, there are examples of solar thermal applications at airports that can illustrate the path forward for a successful project. Case summaries for solar thermal at Brainerd Lakes Airport in Minnesota and Toronto-Pearson Airport are provided in Chapter 5.

1.2.2 Geothermal

Geothermal technologies utilize heat from the earth. There are two primary methods for extracting geothermal energy: conventional or "true" geothermal which taps heat originating from the earth's core, and shallow geothermal or ground source heat pumps which utilize the constant temperatures below ground for heating and cooling (*13*). Geothermal is considered to be an important baseline renewable energy source because it is the primary resource with the potential of providing carbon-free heating and cooling.

1.2.2.1 Conventional Geothermal

Conventional geothermal technologies extract energy from water heated underground by the earth's core. While there are a number of different types of systems and technologies, the most fundamental technology, referred to as hydrothermal, extracts hot groundwater occurring near underground heated fissures. New methods, referred to as Enhanced Geothermal Systems (EGS), pump fluids underground where existing water and soil permeability does not exist, allowing for the isolated heat energy underground to be unlocked. The heated water can be used to provide power for heating and cooling, or it can be used to power a steam turbine and generate electricity.

Conventional geothermal can be used as a local power source to meet on-site energy needs or act as a regional power source supplying a grid or district energy network. Costs associated with generating conventional geothermal energy are directly associated with the depth of drilling and infrastructure installation necessary to tap into these hot underground resources. Therefore, the most economical sites for developing geothermal projects are in areas where the molten core occurs close to the earth's surface.

Conventional geothermal is typically more economical in a utility-scale application as larger electricity generating plants provide power to the utility grid (*14*, *15*). The potential of specific areas in the American west to provide power from geothermal resources has been investigated since the earliest days of the development of the national electrical grid. A site in Northern California known as The Geysers, which first generated electricity in the 1920s, was the site of the first United States modern geothermal plant completed in 1960, and today is the largest complex of geothermal power plants in the world (*16*). The site has shown that underground water reservoirs become depleted overtime and major investments have been made to pipe treated wastewater from urban centers to The Geysers to replenish the reservoirs.

The growth of geothermal power production has been modest in the United States compared with development overseas. Geothermal production at the end of 2013 was 3,442 megawatts (MW) with 85 MW or about 16% of global installations (*17*) added during 2013. This level is relatively small when compared to 4,751 MW of solar and 1,084 MW of wind generated in the United States. The Department of Energy's Geothermal Technology Office operates an active research and development program that is supporting geothermal technology development including demonstration projects with the intention of developing a sustainable and cost-effective geothermal power industry (*18*).

Airports have not been a viable source for conventional geothermal projects due to the specific geographic requirements of conventional geothermal and the focus on utility-scale electricity generation development due to its potential to be more cost effective.

1.2.2.2 Geothermal Heat Pumps

Geothermal heat pumps, also called ground source heat pumps (GSHP), utilize the constant temperature in the ground and its capacity to store energy to provide heating and cooling. At about 10 feet below the earth's surface, the temperature remains constant between 50°F and 60°F, depending on latitude. The geothermal heat pump facility circulates a fluid through a closed-loop system which is cooled to say 50°F in summer (when above ground temperatures are 80°F or more) and warmed to 50°F in winter (when above ground temperatures are 30°F and less) (see Figure 1-7). The heat pump is a mechanical device that transfers heat from the fluid to conditioning interior spaces. In winter, heat is extracted from the fluid and the colder liquid is returned to ground. In summer, the colder fluid is utilized for cooling and heated fluid returned underground and stored for winter use (*19*).

One of the advantages of geothermal heat pumps is that there are no particular geographic limitations or specific geologic requirements for installing such systems. Furthermore, the loops are installed under the ground and above ground facilities are typically located inside buildings providing enhanced flexibility in locating systems within existing site conditions. Ground loops can be installed vertically where above ground construction access is limited or can be built horizontally, potentially limiting installation costs. However, different engineering strategies may need to be employed based on site-specific geophysical characteristics and costs can vary based on the relative difficulty of system installation.

The primary benefit of installing a GSHP system is a reduction in energy consumption and a resultant decrease in utility expenses (*20*). In terms of heating, GSHP systems have a coefficient of performance of 3.0 or higher. This means that for every unit of energy consumed, three units are generated (i.e., GSHP systems are 300% or more efficient). In comparison, the efficiencies of most boiler-based heating systems are 80% or less. For space cooling, GSHP systems have an energy-efficiency ratio in excess of 14.5 (27 is the market best), which is approximately twice the energy-efficiency ratio of conventional air-conditioning. Energy savings of 70% can be achieved; 50% is the norm (*21*).

Other GSHP system benefits include:

- Increased conditioned space comfort: Heat pumps run almost constantly, ramping heating and cooling up and down as needed (i.e., there are no on-off fluctuations); provide superior humidity regulation; and are quiet.

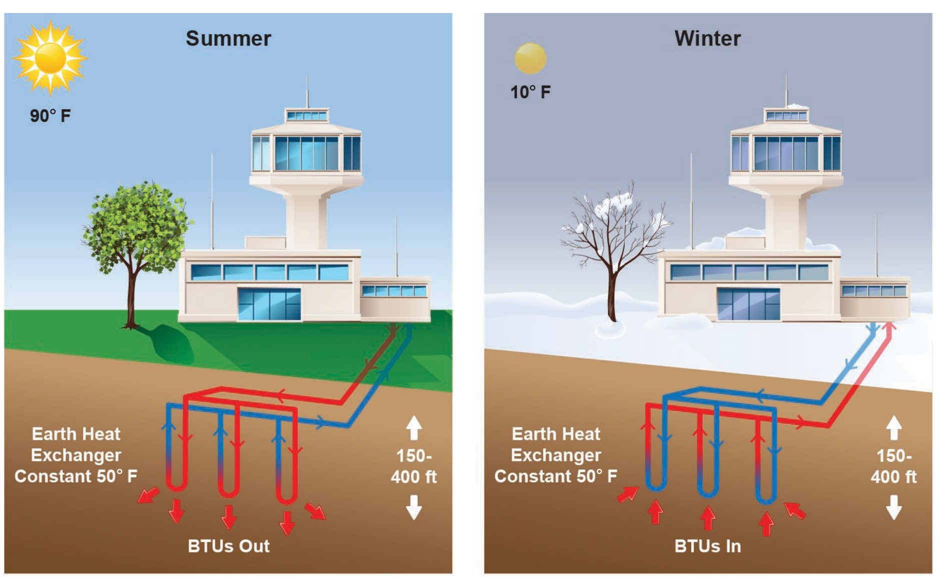


Figure 1-7. Schematic of geothermal heat pump.

- Safe operation: Heat pumps are electric and do not combust fuel, which also results in significantly reduced greenhouse gas emissions.
- Free to low-cost domestic hot water: This can be achieved by adding a de-superheater or an additional heat pump or by installing a three-phase heat pump.
- Low operations and maintenance costs: Annual costs are typically 50% to 70% less than conventional systems.
- Long warranty periods: Typically, warranties are 25 years for the interior components and 50 years for the loop-field piping.

GSHP systems work optimally in climate regimes where heating and cooling are relatively balanced. However, they are versatile, and with minor system adaptation, modification, or hybridization, GSHP systems can be deployed effectively in heating-dominated or cooling-dominated climates. Additionally, GSHP systems can be used to supply hot water for domestic purposes and/or commercial or industrial applications (e.g., snow melting, brewing).

System performance and cost-effectiveness of projects may vary by geographic region and each individual project site requires an assessment to determine cost-effectiveness. All systems must be balanced to accommodate heating and cooling needs of the particular climate (e.g., more heating in the north, more cooling in the south). Thus, it may not be economical to size a system to fulfill the entire heating or cooling capacity of a particular season if there is a dramatic disparity in power demand between summer and winter. Cost-effectiveness will also be influenced considerably by not only specific elements of a project site's design, but also the availability of financial incentives from state policies and the local cost of power that the geothermal will be replacing (i.e., displacing high cost energy is more economical than low cost energy) (*22*).

A number of airports have installed GSHP largely associated with new terminal construction projects. These projects have primarily received supplemental funding from the FAA's Voluntary Airport Low Emissions (VALE) Program allocated to reducing on-airport emissions at facilities located in U.S. EPA designated areas not meeting ambient air quality standards of the Clean Air Act. These projects are compatible with existing airport activities as all of the facilities are located underground or inside buildings avoiding conflicts with airspace protection. Chapter 5 presents case summaries on two GSHP projects at Juneau Airport and Portland Jetport in Maine. Table 1-1 provides a list of GSHP projects that have been installed at airports around the world.

1.2.3 Biomass

Biomass (also referred to as bioenergy and can include biofuels) is organic material that comes from plants and animals. Plants store the sun's energy which is then consumed by animals and is released slowly through decomposition. Biomass energy can be released at higher rates through combustion, which also accelerates the release of carbon dioxide stored in the plant material. Biomass is considered renewable because it comes from natural processes that can be produced and consumed through a relatively short and sustainable time period as illustrated in Figure 1-8 (*23*, *24*).

Biomass can provide potential revenue and cost savings in two ways: either by growing crops on airport land as a feedstock of bioenergy; or by burning the feedstock to produce energy through combustion. It is important to note that bioenergy, while renewable, is not emissions free. However, through its life cycle, it is considered to release and capture equal amounts of carbon and therefore can be classified as carbon neutral.

1.2.3.1 Feedstock Propagation

A variety of organic materials can be used to produce bioenergy. These include materials that are a waste product from other activities, such as wood waste from logging and the manufacturing of forest products, and domestic wastes that would otherwise be disposed of in landfills.

Table 1-1. GSHP projects at airports around the world.

Airport	Country/State	Location	Capacity
Austin-Straubel	WI	Snow Removal Building	n/a
Binghamton	NY	Apron Snow Melt	n/a
Central Wisconsin	WI	Terminal	n/a
Dane County	WI	Airfield Maintenance Building	n/a
Dickinson	ND	Terminal	10 wells
Duluth	MN	New Terminal	80 wells
Juneau	AK	Refurbished Terminal	108 wells
Knox County	ME	New Terminal	12 wells
Nantucket	MA	New Terminal	3 wells
Olso-Gardermoen	Norway	Terminal	18 wells
Outagamie	WI	Fixed-base Operator (FBO)	20 wells
Paris-Orly	France	Terminal	2 parallel shafts
Portland	ME	New Terminal	120 wells
South Bend	IN	Concourse A	n/a
Stockholm-Arlanda	Sweden	Terminal	n/a
University Park	PA	Refurbished Terminal	33 wells
Zurich	Switzerland	Terminal	440 wells

n/a: information not available

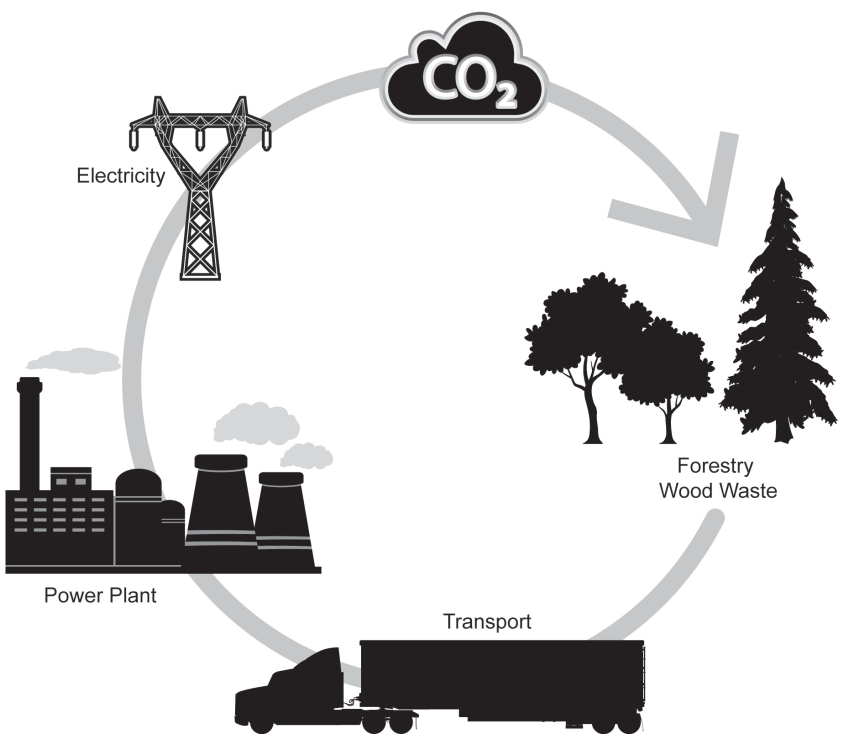


Figure 1-8. Life cycle of biomass power generation.

Other feedstock can be deliberately grown to meet the demand for a bioenergy feedstock with the most common example being farming of corn to produce ethanol as an additive to gasoline.

In current practice, most biomass energy plants that utilize organic material to produce heat or electricity are typically fueled by wood waste or trash. Many are located close to regions with a forestry industry, which limits transportation costs, and also provides some compensation for the wood waste that is produced and offsets costs necessary for disposal. Likewise, waste-to-energy power plants provide an alternative means for disposal of domestic wastes and potentially construction and demolition debris where landfill capacity is limited, and costs for shipping waste long distance are not economically or environmentally preferable.

However, the aviation industry is investing a considerable amount of resources developing potential alternative jet fuels, some of which may be developed by organic materials including specific crops that may be grown domestically (*25*, *26*). Some of the crops identified as being a feedstock for alternative jet fuels are oil seed plants including Camelina and Jatropha. The U.S. Department of Agriculture's (USDA) National Wildlife Research Center is currently conducting field studies on the suitability of growing oilseeds on airport land from a wildlife hazard perspective. The research is not expected to be completed until 2016 (T. DeVault, personal communications, January 5, 2015). In 2012, Wayne County Airport Authority (WCAA), operator of Detroit Metropolitan (DTW) and Willow Run airports, partnered with Michigan State University (MSU) Extension to assess the potential to grow biofuel crops on airport property. These initiatives associated with assessing the potential compatibility of growing biofuel crops and generating revenue are described in Appendix B. While not an immediate example of potential revenue, feedstock propagation represents a potential future opportunity for certain airports that might become part of the alternative jet fuel supply chain and should be considered when conducting long-term master planning activities.

1.2.3.2 Combustion

Biomass combustion, unlike biofuel production, utilizes organic matter that has not been overly processed to produce electricity or heat. Some examples of biomass fuels are wood, crops, animal manure, and human sewage. Biogas, produced from the decomposition of organic matter, can also be combusted to produce heat or electricity. The most utilized forms of biogas come from methane released from old landfills and produced by anaerobic digestion facilities fueled by food wastes.

Biomass is burned to produce electricity and heat in the same manner that traditional fossil fuels such as coal, oil, and gas are used. To produce electricity, the biomass is burned to boil water, which produces steam to drive a steam turbine and generate electricity. The waste heat can be stored in water to provide hot water heating as a form of co-generation.

Biomass power facilities are most often found close to low cost sources of fuel which is typically produced from wood waste, and are more concentrated in areas where there is a commercial forest products industry. Logging operations produce wood scraps that cannot be used in the forestry products. These scraps can be sold as is or processed into wood pellets for residential and commercial heating fuels. Large utility-scale plants often utilize unprocessed biomass whereas small facilities require a more uniform product that can be delivered, stored, and accessed.

In some locations, waste-to-energy power plants have been approved to receive and incinerate domestic trash as a fuel for power generation (*27*). A challenge with waste-to-energy is ensuring that the trash does not include harmful chemicals that could become airborne after incineration. Some energy is being produced by landfill gas facilities that release and burn methane trapped in the landfill to produce electricity. This methane would otherwise remain trapped or released to the atmosphere slowly over time. Anaerobic digestion is an old technology given new life in areas that are restricting the landfilling of food wastes particularly produced in large quantities by large food producers. Anaerobic digesters accelerate the decomposition of the food wastes producing gas that can be burned to generate electricity.

There are a few examples of biomass power plants at airports including one at Grant County Regional Airport in John Day, Oregon, which is included in the case summaries in Chapter 5. There may be other opportunities to retrofit an airport's heating system to accept biomass in the form of wood pellets as has been accomplished at Grant County. However, the challenges of deploying biomass at airports include proximity to the biomass fuel source, additional traffic generated by delivering the biomass to the airport, and space constraints associated with storing wood pellets and other biomass fuels on-site.

1.2.4 Wind

Wind power is responsible for much of the significant progress in large scale renewable energy generation throughout the world. No other renewable energy power generation can match the capacity of a traditional power plant (when the wind is blowing). These successes have been achieved by building taller wind turbines comprised of lighter and stronger materials to reach higher into the sky and extract a more consistent wind resource (*28*). While these taller turbines have improved the efficiency of wind energy generation, they also can create safety hazards for air navigation.

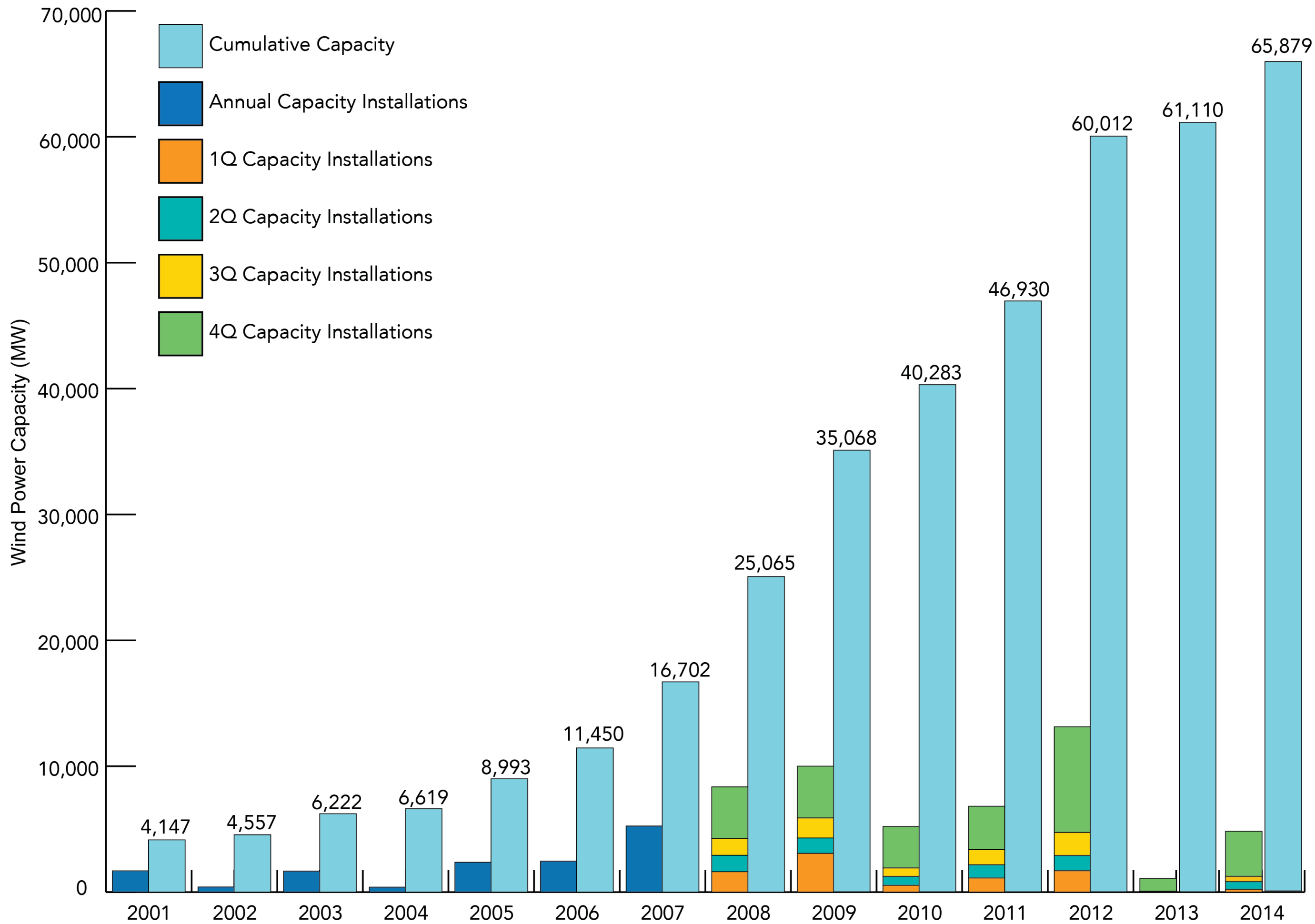
As shown in Figure 1-9, wind generation capacity in the United States has increased from 4 gigawatts (GW) in 2001 to 65 GW in 2014, and wind could supply 20% of the nation's electricity by 2030, equating to 300 GW (including 54 GW of offshore wind) (*29, 30*).

A variety of incentives have catalyzed wind power growth, including tax credits, purchasing mandates by federal agencies, and state level RPS (*31*). Examples of renewable energy purchasing goals include the U.S. Department of Energy's (DOE) goal of 20% by the year 2030, the Department of Defense (DOD) goal of 25% by 2025 (*32*), and the 2004 Colorado Renewable Energy Requirement Initiative whereby Colorado became the first state to pass an RPS. Approximately half of all states have followed suit with RPS development, ensuring a growing role for wind energy production (*33*).

The following section briefly describes the two types of wind energy projects—utility-scale and building-integrated—and their applicability to airports. The basic components of a wind turbine generator referred to in the sections below are identified in Figure 1-10.

1.2.4.1 Utility-Scale Wind

The American Wind Energy Association (AWEA) defines a utility-scale wind turbine as one that has a nameplate capacity of 100 kW or larger (*34*). Today, wind turbines on land have a nameplate capacity of 3 MW (or 30 times the generation capacity of a 100 kW unit), and offshore wind turbines can be 6 MW and larger in capacity. These larger generators are viable because they can be placed on taller poles to capture more consistent wind; 100 kW generators may be placed on tubular towers that are 100 feet above ground level whereas the 3 MW generators are placed on 500 foot tall towers. Regardless of individual wind turbine size, single units may be placed at a load center to supply on-site electricity and limit the amount required to be drawn from the grid. Multiple wind turbines (typically in larger size categories) are grouped together in a wind farm to generate large amounts of electricity to supply the electric grid. The greatest amount of wind energy development has occurred in the Midwest where the wind blows at higher consistent velocities across relatively flat terrain, unobstructed by mountain ranges and forests, and wind turbines can be located in the existing agrarian landscape providing supplemental income for farming families without disturbing their daily operations. Wind has also been developed in



Source: American Wind Energy Association

Figure 1-9. Annual and cumulative installed wind power capacity in the United States.

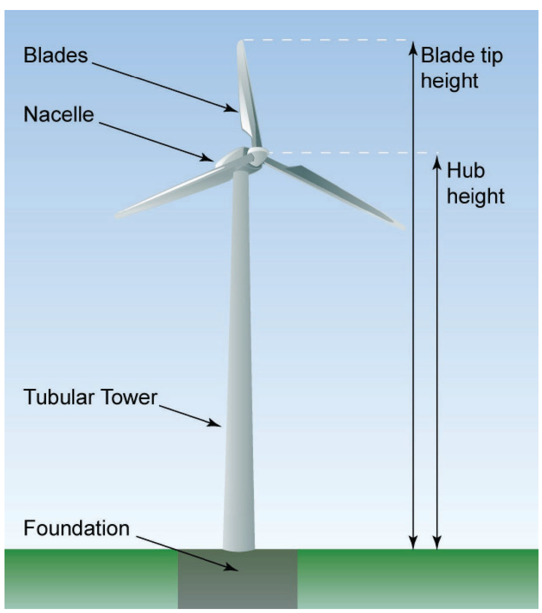


Figure 1-10. Components of a utility-scale wind turbine.

other parts of the country on plateaus, mountain passes, ridgetops, and some coastal areas where wind is favorable and local acceptance has been gained. As very large structures on the landscape, wind turbines are typically incompatible with aviation, and the FAA and military have often expressed concern about airspace impacts either directly from the structure or through impacts on radar facilities. This issue is described in greater detail in Section 2.6.4.

Despite the size of the structures and their potential to impact airspace, a handful of utility-scale wind turbines have been constructed on airport property to provide on-site electricity generation. Projects at Burlington International Airport (BTV) in Vermont and East Midlands Airport in the United Kingdom (UK) are provided as case summaries in Chapter 5.

1.2.4.2 Small Wind

Small wind comes in two forms: stand-alone wind turbines with a generation capacity of less than 100 kW similar in design to a utility-scale turbine and built-environment designs. A picture of a built-environment wind turbine from the Wind Turbine Lab at the Museum of Science in Boston is shown in Figure 1-11.

Stand-alone wind turbines are typically less than 100 feet tall and provide on-site power for smaller electricity loads from commercial buildings to farms to single residences. Their design components are typically similar to those of utility-scale wind turbines shown in Figure 1-11, though other designs like a two-bladed turbine and an egg-beater design are also utilized. Stand-alone wind turbines less than 100 kW have not been installed at airports most likely because of the increasing cost of electricity produced with the decreasing size of the unit.

Built-environment wind turbines (also referred to as architectural wind) are wind turbines that are mounted on the roof of building structures. They are much smaller than utility-scale wind turbines primarily because the structure that they are mounted on is not designed to accommodate the load the wind causes. They have smaller blades and a smaller area to capture the wind. The capacity of each wind turbine is usually between 1 and 10 kW and it is common that multiple structures are deployed to increase the overall electricity generating capacity. As with stand-alone wind turbines, experience has shown that the smaller the generator is, the more expensive the electricity or cost of electricity produced.

Small wind has been constructed at a handful of airports. Table 1-2 provides a listing of identified projects. The project at Boston Logan is described in more detail as a case summary in

Source: Museum of Science, Boston

Figure 1-11. Example of built-environment wind turbines.

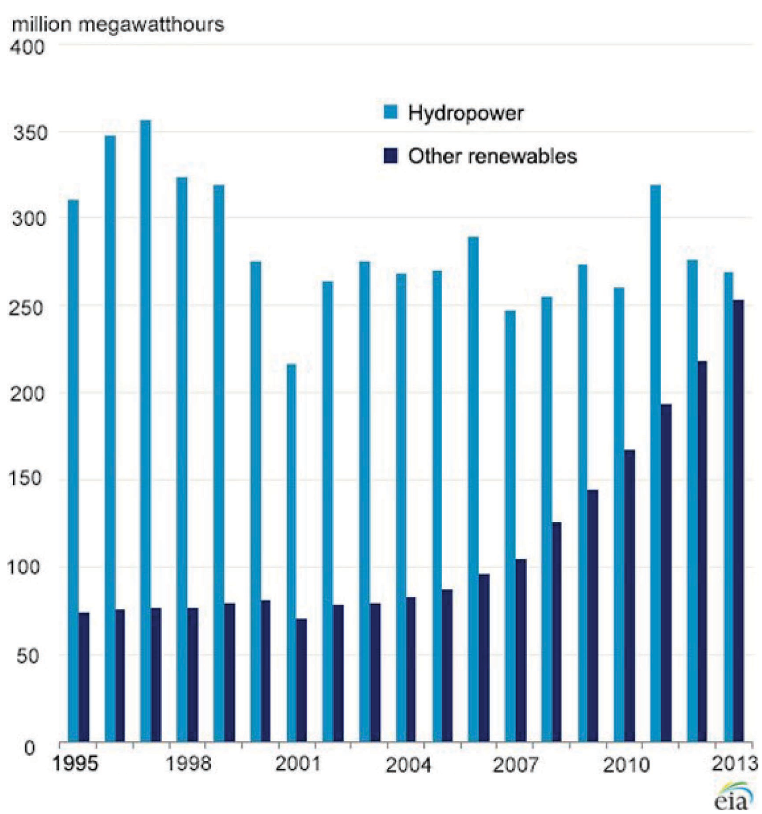
Table 1-2. Small wind installed at airports.

Airport	Location	Wind Turbine	Capacity
Boston-Logan	Administrative Building	Aeroenvironment	20 units, 20 kW
Honolulu	DOT building	Aeroenvironment	16 units, 16 kW
Martha's Vineyard	Airfield	Eastern Wind	1 unit, 50 kW
Minneapolis-St. Paul	Airport Fire Station	Aeroenvironment	10 units, 10 kW
Oakland County - Michigan	Ground	WindSpire	3 units, 7.2 kW
Wayne County - Detroit	Ground	WindSpire	6 units, 7.2 kW

Chapter 5. Experience suggests that these wind turbines are more of an architectural treatment and symbol of a renewable energy future than a substantive producer of cost-effective renewable energy.

1.2.5 Hydropower

Hydropower is produced by moving water and has a long history of providing power for human uses. Currently, it is the largest source of electricity generation from renewable sources in the United States. In 2013, hydropower contributed 6% of all electricity in the United States and 52% of all renewable electricity sources in the country (*35*). However, the amount of electricity generated from other sources such as solar and wind has increased substantially over the past years, while hydropower generation has been relatively constant as shown in Figure 1-12.



Source: U.S. Energy Information Administration, *Electric Power Monthly* (February 2014).

Figure 1-12. Hydropower and other renewable sources of electricity: 1995–2013.

Traditional hydropower sources are generated by damming rivers and passing the detained water over the dam. Due to the significant environmental consequences associated with dams, new applications are focused on capturing energy from free flowing waters both in river and ocean settings (*36*). Some public policies have been enacted to promote small scale hydropower including the Hydropower Regulatory Efficiency Act of 2013 (*37*). While its applicability to airports is limited to those adjacent to flowing rivers and ocean sites, a brief summary of the different types of hydropower and their potential application to airports is provided.

1.2.5.1 Riverine Hydro Power

Most of the hydropower production in the world comes from turbines located in dams fed by flowing rivers (e.g., riverine). Water is detained behind dams and the impounded water is passed over the dam with the gravity of the falling water turning a hydro turbine. As dams retain a significant amount of water, electricity can be generated in an uninterrupted fashion as upstream water flow constantly replenishes the reservoir above the dam. Historic dams provided on-site power for industry. Modern dams have been constructed to generate utility-scale electricity directly into the electric grid. Hydropower constitutes a large share of the regional power market in particular areas of the country such as the Pacific Northwest where there are large rivers with limited commercial and residential development nearby.

As part of the movement to decentralize power generation and minimize the environmental impacts of utility-scale hydropower generation, new riverine power technologies and projects have been proposed and demonstrated in recent years. In some cases, old dams that are not being used for power generation are being retrofitted with low-impact devices that pass water through the dam without impact to aquatic life (see Figure 1-13). In other cases, new technologies are being located in flowing rivers to capture electricity without impounding the river using so-called run-of-the-river technologies. These technologies are not utility-scale in nature and are most appropriate to supply electricity for an energy source operating adjacent to the river. When siting such facilities, it is important that they not obstruct the rights of navigation.

Airports in certain areas of the country may obtain their electricity from large scale legacy hydropower plants that are feeding electricity to the grid. However because the hydropower is mixed with many other regional electricity generating sources including those from fossil fuel power plants, airports and other retail customers make a direct claim to using renewable energy. New hydropower projects, while less benign on the environment, are difficult to develop due to the highly regulated environment associated with work in wetlands and waterways.

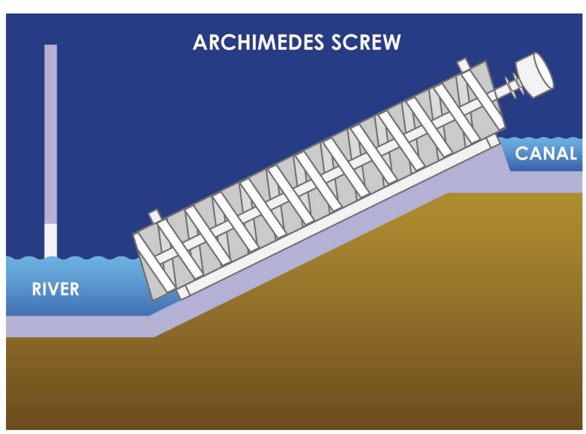


Figure 1-13. Existing dam retrofitted with advanced hydropower technology.

Opportunities may exist for pilot projects to connect individual projects and direct the power to an airport, though no such projects are known at this time.

1.2.5.2 Wave Power

Wave energy can be generated in coastal environments subject to wave action (*38*). One of the advantages of wave power is that it can be predicted in a matter of days allowing electric system operators to forecast its contribution to the grid mix and make adjustments to other sources as necessary. A disadvantage of wave power is the difficulty in installing, operating, and maintaining facilities in the ocean. In the United States, wave resources are strongest on the west coast due to the long fetch of wind moving across the Pacific Ocean.

Wave energy generation technology remains in an early stage of development. Technologies are being tested in the water at the European Marine Energy Centre (EMEC) in the United Kingdom (UK). There have been a few wave test installations in the United States including in Hawaii, Massachusetts, North Carolina, and Oregon. Figure 1-14 shows a device being developed by a Massachusetts-based company.

While wave energy is not seen as being a major contributor to the world's electricity generation in the near-term, the volume of the stored energy in the ocean is massive and it will remain of interest to countries to investigate cost-effective ways to extract wave and other ocean energies to generate electricity. Therefore, it is possible that pilot projects could be located near coastal airports to demonstrate the potential for wave energy to provide on-site electricity generation.

1.2.5.3 Tidal Power and Ocean Current Energy

Tidal and ocean current energy is extracted from ocean areas in a manner similar to run-of-the-river or riverine hydropower discussed above. With tidal power, turbines are located in coastal inlets where strong currents are created by the ebbing and flooding of the tides (*39*). Because the tides flow in two directions, the turbines must be designed to accommodate the bi-directional nature of the flow. Conversely, ocean current power occurs where there are major currents in the ocean that always flow in one direction. The best known current in the United States is the Gulf Stream that flows north from Florida along the east coast up to Cape Cod and across the Atlantic Ocean.

Tidal and ocean current energy technologies, like that of wave power, are in an early stage of development. A few technologies are being tested at EMEC in the UK and there is a commercial

Source: Resolute Marine Energy

Figure 1-14. Wave energy converter.

Source: Ocean Renewable Power Company

Figure 1-15. Tidal energy device deployed in Maine.

scale installation that has been operating since 2011 in a coastal inlet in Northern Ireland. Several technologies have been demonstrated in the United States in Maine, New York, and Washington State. Figure 1-15 shows a device that was deployed in Lubec, Maine in the fall of 2013. There have been no demonstrations at ocean current sites, though studies have been undertaken in the Gulf Stream off the east coast of Florida.

Opportunities for demonstrating tidal energy technologies at airport sites are possible but generally unlikely with a few exceptions. Pilot sites would need to match up airports near strong tidal resource areas. Such a condition could exist at Anchorage International Airport (ANC) but the challenges of developing a tidal energy project at an airport location are significant.

1.2.6 Fuel Cells

Fuel cells generate electricity through a chemical reaction that is catalyzed by an outside fuel source. Once the chemical reaction commences, the splitting atoms create a flow of electricity. The by-products are heat and emissions depending on the initial fuel source. Most contemporary fuel cells have a source of natural gas that catalyzes the chemical reaction that will result in some limited amount of air emissions. However, because the fuel use is limited to sustaining the reaction but not producing the electricity, emission levels are relatively low. Future fuel cells could be powered by hydrogen, which once cycled through the fuel cell catalytic process, would have as a byproduct water and oxygen (see Figure 1-16) (*40*).

Fuel cells can generate both electricity and heat. Like solar, they are a modular technology that can be sized to the appropriate use. Fuel cells to power transportation are sized to fit in a car. Larger fuel cells look like a storage shed providing a stationary electricity source to nearby loads.

One of the most valuable aspects of a fuel cell is as an emergency electricity generation source that is not connected to the electrical grid and can supply on-site power when the electric grid goes down. Many technology firms with data centers have installed fuel cells to provide reliable backup power in the event of a potential brown or black-out condition. Utilities have also installed large stationary fuel cells as part of demonstration projects to improve the reliability of the grid in advance of a potential system-wide power disruption.

The DOE is partnering with Federal Express (FedEx) and Plug Power, a fuel cell manufacturer, to provide FedEx with 15 hydrogen powered fuel cell ground support equipment (GSE) units.

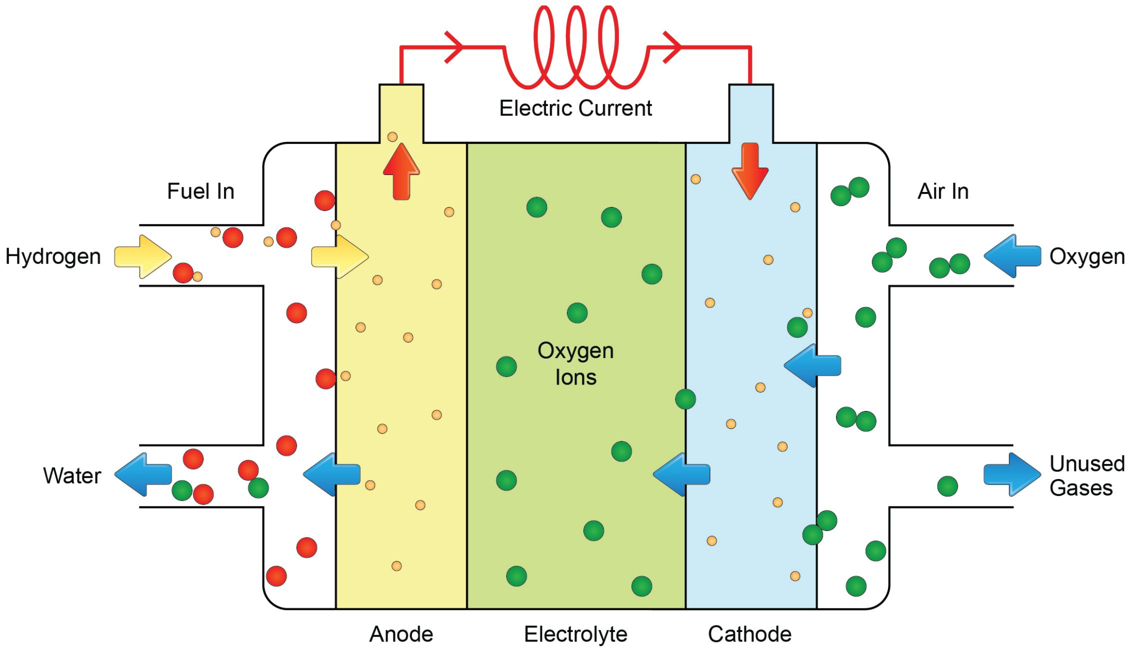


Figure 1-16. Schematic of a fuel cell.

The units were expected to be delivered by the end of 2014 for use at FedEx's hub at Memphis International Airport (MEM) after it demonstrated the technology earlier in the year. According to Bloom Energy, a major fuel cell manufacturer in California, airports that are interested in shoring up backup power as part of a microgrid have also been exploring the option of installing stationary fuel cells. While fuel cells remain relatively expensive, they could provide value as a reliable backup source necessary to power critical infrastructure similar to that of hospitals, in that airports also need to improve their operational reliability during emergency situations.

1.3 Project Participants and Interested Parties

The implementation of a successful renewable energy project on airport property requires leadership from the airport and oversight from the FAA. However, the role of key internal airport department personnel in concept development and the interests of external stakeholders through the review process may not be obvious. This section introduces the reader to the central project participants both internal to the airport organization and externally, which are shown in Figure 1-17, and highlights their roles and interests.

1.3.1 Internal Participants

Internal participants are responsible for developing the project concept, assessing its technical and financial feasibility, developing a defensible plan for locating and financing the project, and building support from decision makers at the airport prior to engaging other interested parties. Key elements of this process are ensuring that the projects are compatible with airport activities and avoiding impacts to sensitive airport receptors including glare impacts from solar PV or radar interference from wind power. These topics are discussed in more detail below in Section 2.6. In addition, a strategy for ownership structure needs to be evaluated early on in the decision-making process to help determine the key financing options. These options are addressed in greater detail in Section 2.5.

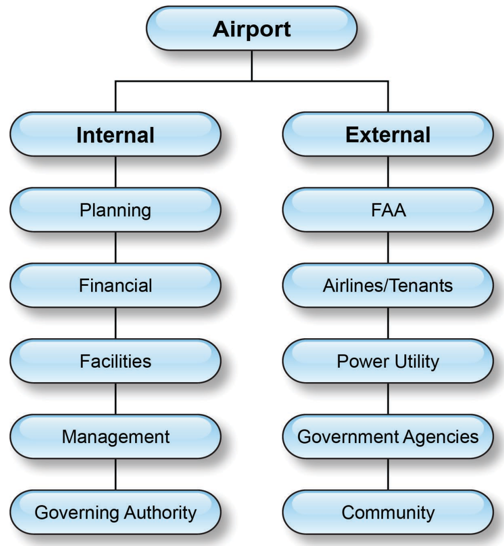


Figure 1-17. Stakeholder engagement.

1.3.1.1 Planning

The project concept will initially require input from planning professionals internal to the airport. They will want to review the type of technology proposed, alternatives for siting relative to the master plan, and consistency with existing and future infrastructure. The planning group will be familiar with other projects that have been undertaken and issues that have arisen in project planning and construction. Their input can be used to verify potential fatal flaws such as conflicts with the airport layout plan (ALP), potential sensitivity to navigational aid (NAVAID) interference or glare impacts, and environmental impacts.

1.3.1.2 Financial

As soon as a feasible concept plan and site has been identified, the internal project lead should engage the airport's financial planners to evaluate financial structures that could be used to fund the project. The financial evaluation will consider the Airports Capital Improvement Program (ACIP) to identify whether there are leveraging opportunities or barriers associated with the current plan. It will also evaluate unconventional sources of FAA funds (such as VALE or the Section 512 Program), as well as viability of a public-private partnership. Based on this coordination, the internal team should have identified if the project is viable and the information needs identified along with what the options may be for financing it with preferred and alternative funding mechanisms.

1.3.1.3 Facilities

While the facilities group may be initially engaged during the planning process to confirm existing and near-term electrical infrastructure requirements, once a financing plan is developed, it should be engaged in evaluating integrated design of a renewable energy system and the practical considerations associated with long-term operations and maintenance. The facilities group can help improve project design by evaluating how the system installation would physically interconnect with the existing electrical network. It will have a strong understanding of the affected system components and their capacity to accommodate the proposed project concept. Facilities staff will also be familiar with the operations and maintenance of electrical facilities and can begin to engage key contacts with the utility company about the project, its design and interconnection approval process.

1.3.1.4 Management

Key members of management should be consulted during the early stages of developing the project concept to make sure the airport is receptive to pursuing a renewable energy project. However, once the project concept has been vetted through the different areas of internal expertise, the airport management should be engaged to affirm its commitment. At this stage, management will want to understand all of the planning, facilities, regulatory and financial aspects of the project. Based on the project manager's communication of the problem and solutions provided by the renewable energy project, management will evaluate all aspects of the project before proceeding to the governing authority for a formal decision to proceed.

1.3.1.5 Governing Authority

The airport governing authority varies among airport organizations, though many are advised by a board of advisers that conducts business at public meetings. It is often prudent to advise the board early about different project activities, including pursuing new projects such as developing renewable energy. The board will want to have answers to many of the same questions that the management will have addressed during the internal review. Several board meetings are typically necessary to answer questions from the board and the public before proceeding with a formal vote on the project. Authorization may include funding, transfer of property rights, or pursuing a strategy that might be followed up by future board actions.

1.3.2 External Stakeholders

1.3.2.1 FAA

The FAA has a significant oversight role at all federally obligated airports to ensure safe and efficient air transportation and to protect the long-term viability of the air transportation system. This responsibility includes evaluating decision-making that may have an effect on the long-term productivity of the airport business. For renewable energy projects, the FAA's involvement will focus primarily on preservation of airspace, protection of aeronautical uses, oversight of property rights and value, and authorization of federal funding.

Airports should initially contact their FAA representative at the airport district office. The discussion should start with appropriate staff that they work with on planning issues to ensure that the project is consistent with the Master Planning and ALP and does not obstruct the future development of aeronautical uses. At the same time, the air traffic division should be consulted about the location of navigational aids and the proximity of the project to FAR Part 77 surfaces to determine that the project will not negatively impact airspace safety. If a lease is being considered, the FAA property division should be engaged about the lease approval process and procedures for documenting fair market value for any lease. For FAA funding through the Airport Improvement Program (AIP) or VALE, the airport will need to discuss its ACIP and include the renewable energy project in its ACIP when filed annually with the FAA regional office.

1.3.2.2 Airlines/Tenants

For commercial service airports, airlines should be consulted on any projects that may affect their rates and fees. Airlines evaluate the short-term financial benefits of such investments and look to see cost savings that will be provided. Other tenants, both aeronautical and non-aeronautical, should be informed about a proposed renewable energy project as part of the regular tenant communication programs implemented by the airport. These tenants will be interested in proposed airport improvements and how they may affect their business as well as the potential for any rate increases in future lease agreements. Tenants may also be interested in partnering with the airport on a renewable energy project if such a project can provide a mutual benefit.

1.3.2.3 Electrical Utility

The electrical utility is a key stakeholder for planning and implementing any power infrastructure project. The utility has unique expertise on the technical considerations for interconnecting a power generation project to the existing electric network. It will also advise the airport on the interconnection application process and timeframe. The utility should be seen as a partner throughout the process engaged with the airport and its technical consultants.

1.3.2.4 Government Agencies

A number of different government agencies may be interested in the proposed project depending on the airport's location and political geography. Most airports are a division of municipal, county, or state government or are a separate regional or state authority. Irrespective of the specific governing structure, the sister agencies of the airport will be most affected by the activity as they likely participate in intergovernmental coordination including implementation of master planning and shared public policy goals. Those that are most relevant to a renewable energy project include sustainability, renewable energy generation, and greenhouse gas emission policies. Other government agencies may be part of the approval process. These include natural resource agencies authorized to review and approve development projects and their potential effects on wetlands and historic resources, as two examples. Meeting with agency representatives early in project planning will help avoid any permitting fatal flaws and build support where alignment with government policy goals can be demonstrated.

1.3.2.5 Community

Renewable energy projects generally have a broad public appeal particularly in urban areas where air quality degradation is of concern. In rural areas, a renewable energy project on airport property may be seen as having potential economic development benefits. Other renewable energy projects could be seen as having a negative aesthetic impact depending on the visibility of the technology. In all cases, engaging the community is an important part of building general support for the project. Informing the community of the project through existing communication processes, including newsletters, websites, information kiosks, and public meetings, will help the airport avoid misinformation and misunderstanding about the project.

1.4 Essential Baseline Information

Before proceeding with the investigation of the renewable energy project, the airport should become acquainted with some essential information focused on energy that it can readily get access to but may not be familiar with. These include utility bills, electrical meters, and state incentive programs.

1.4.1 Utility Bills

Utility bills can be complex and difficult to understand. Spending some time reviewing the utility bill and consulting with facility staff and utility representatives is essential for planning a renewable energy project. The following description of the utility bill generally applies to both electricity and natural gas, if it is used as a fuel for heating.

Utility bills are typically segregated by individual meter with large airports having multiple electrical meters. The rate (or tariff) paid for the electricity at each meter will depend on the type of customer (e.g., residential, commercial) and amount of electricity consumed at the meter. The total rate for the electricity is determined on a kilowatt-hour (kWh) basis. The total rate is subdivided into the generation rate (i.e., the cost to make the electricity) and the distribution rate (i.e., the cost to deliver the electricity). There may be other add-ons to the bill that are

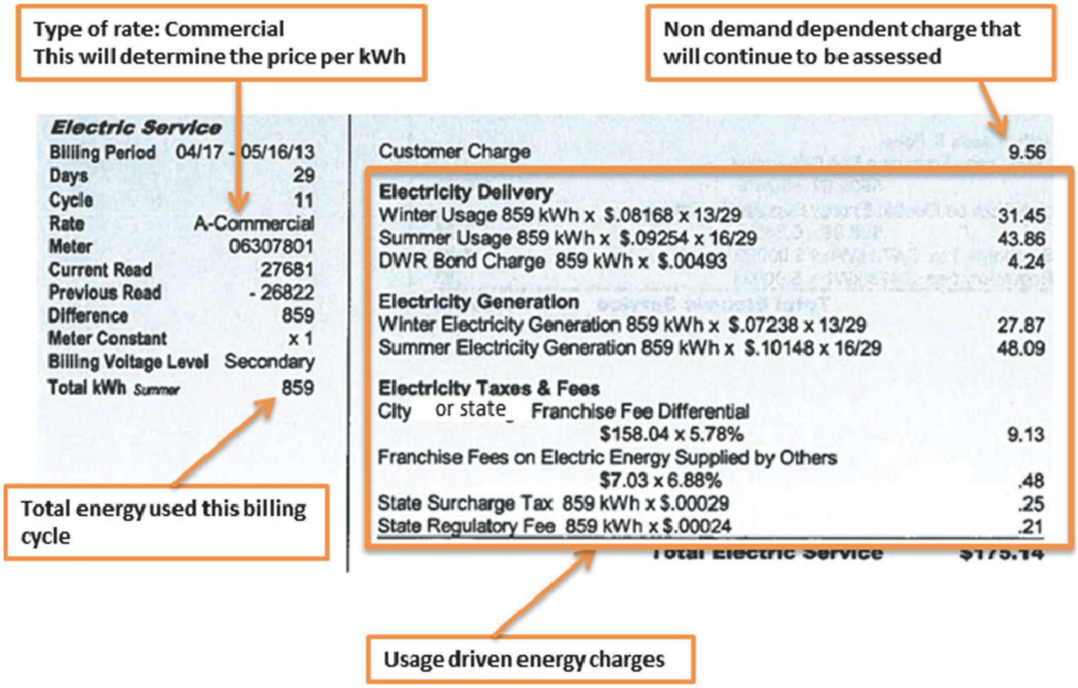


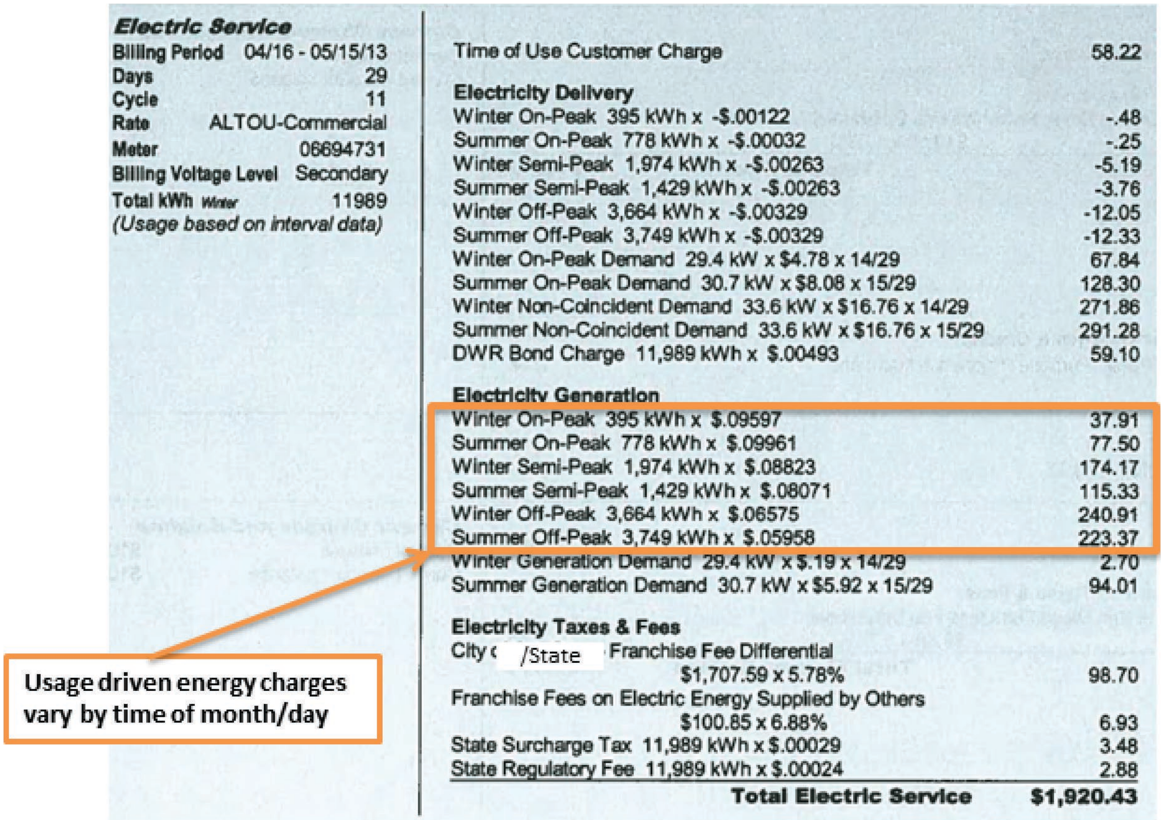
Figure 1-18. Utility bill example showing different rates and charges.

deposited into accounts to fund energy efficiency and renewable energy incentive programs. Figure 1-18 provides an example of a utility bill and calls out some of the specific components and charges.

Utilities have been more regularly implementing time-of-day charge programs as well as demand charges to encourage users to limit their electricity consumption. Demand charges apply a higher usage rate when overall monthly electricity use exceeds an identified threshold. All electrical usage above the threshold rate is charged at a premium. Time-of-day rates apply elevated charges to high demand or consumption times of the day as well as on a seasonal basis to limit use during peak consumption hours such as hot summer afternoons. These programs encourage customer cost savings and reduced demand based on usage but also limit the need for the utility to invest in infrastructure upgrades necessary to provide power at peak usage times. These upgrades are ultimately funded by all customers through rate increases. Figure 1-19 shows an example of a utility bill with time of day and seasonal pricing.

1.4.2 Electrical Meters

Electrical meters are located at various places on an airport to track the amount of electricity consumed for a building or an area and are used to monitor net metering where the excess electricity is produced and sent back into the grid system. Gas meters generally do the same though they are only affiliated with occupied spaces and central heating plants. Meters are particularly important for installing renewable energy generation projects that will provide on-site power as the size of the generating system will need to be sized with the amount of power consumed either on an average or peak use basis. Electrical meters will also provide information on the downstream wire capacity though that information should also be readily available to airport facility personnel and the local utility representatives. As the renewable energy project will need to be connected to the existing power network, the location of meters is a critical element for project siting.



Electric Service
Billing Period 04/16 - 05/15/13
Days 29
Cycle 11
Rate ALTOU-Commercial
Meter 06694731
Billing Voltage Level Secondary
Total kWh Winter 11989
(Usage based on interval data)

Time of Use Customer Charge	58.22
Electricity Delivery	
Winter On-Peak 395 kWh x -$.00122	-.48
Summer On-Peak 778 kWh x -$.00032	-.25
Winter Semi-Peak 1,974 kWh x -$.00263	-5.19
Summer Semi-Peak 1,429 kWh x -$.00263	-3.76
Winter Off-Peak 3,664 kWh x -$.00329	-12.05
Summer Off-Peak 3,749 kWh x -$.00329	-12.33
Winter On-Peak Demand 29.4 kW x $4.78 x 14/29	67.84
Summer On-Peak Demand 30.7 kW x $8.08 x 15/29	128.30
Winter Non-Coincident Demand 33.6 kW x $16.76 x 14/29	271.86
Summer Non-Coincident Demand 33.6 kW x $16.76 x 15/29	291.28
DWR Bond Charge 11,989 kWh x $.00493	59.10
Electricity Generation	
Winter On-Peak 395 kWh x $.09597	37.91
Summer On-Peak 778 kWh x $.09961	77.50
Winter Semi-Peak 1,974 kWh x $.08823	174.17
Summer Semi-Peak 1,429 kWh x $.08071	115.33
Winter Off-Peak 3,664 kWh x $.06575	240.91
Summer Off-Peak 3,749 kWh x $.05958	223.37
Winter Generation Demand 29.4 kW x $.19 x 14/29	2.70
Summer Generation Demand 30.7 kW x $5.92 x 15/29	94.01
Electricity Taxes & Fees	
City /State Franchise Fee Differential $1,707.59 x 5.78%	98.70
Franchise Fees on Electric Energy Supplied by Others $100.85 x 6.88%	6.93
State Surcharge Tax 11,989 kWh x $.00029	3.48
State Regulatory Fee 11,989 kWh x $.00024	2.88
Total Electric Service	**$1,920.43**

Figure 1-19. Utility bill showing seasonal and time-of-day (based on peak use) charges.

1.4.3 State Incentive Programs

While federal incentives for renewable energy are available regardless of geographic location in the country, many states have also passed legislation to encourage the consumption of renewable energy sources and build a renewable energy industry. This is particularly true for solar power because the federal investment tax credit is typically not sufficient alone to generate a cost competitive source of electricity.

States have incentivized local renewable energy development projects by requiring utilities to purchase a certain annual percentage of the electricity it sells to customers in the form of renewable energy thereby creating a separate market for renewable energy. These programs are referred to as a RPS and are discussed in Section 2.4.2. Under these programs, the utility buys the renewable energy at a premium or pays a penalty.

The airport should obtain information on their state's renewable energy incentive programs to understand the potential for a private market for renewable energy, which could lead the airport to select a third party project as the model to pursue. If the state incentives are limited, the airport may want to pursue FAA grant funding.

State incentive programs are very dynamic and their status should be evaluated regularly. Programs apply variably to different utility service providers depending on whether they are public, private, or non-profit organizations. However, state programs applicable to all utility customers are described in the Database of State Incentives for Renewables and Efficiency (DSIRE) website (www.dsireusa.org). The airport could also benefit from contacting its state energy office or a local renewable non-profit organization to learn more about relevant incentive programs. More information on relevant public policy is described in Section 2.4.

CHAPTER 2

Applying Evaluation Factors to Airport Renewable Energy

Airports should consider a variety of factors when evaluating the type of renewable energy technology, its location on the airport, the size of the facility, and type of ownership most appropriate to the airport business. These factors will help define a project concept that preserves airspace safety, avoids environmental impacts, and maximizes financial benefits. This chapter reviews the primary factors to consider associated with the project setting, airport characteristics, relevant public policy programs, ownership options, regulatory compliance, and safety and operation. The specific financial criteria used to evaluate the economic viability of the project are discussed in Chapter 3.

2.1 Project Setting

The specific aspects of the project setting that should be considered when identifying a renewable energy technology and a feasible site include the geographic location of the airport, existing infrastructure, and regulatory and policy context.

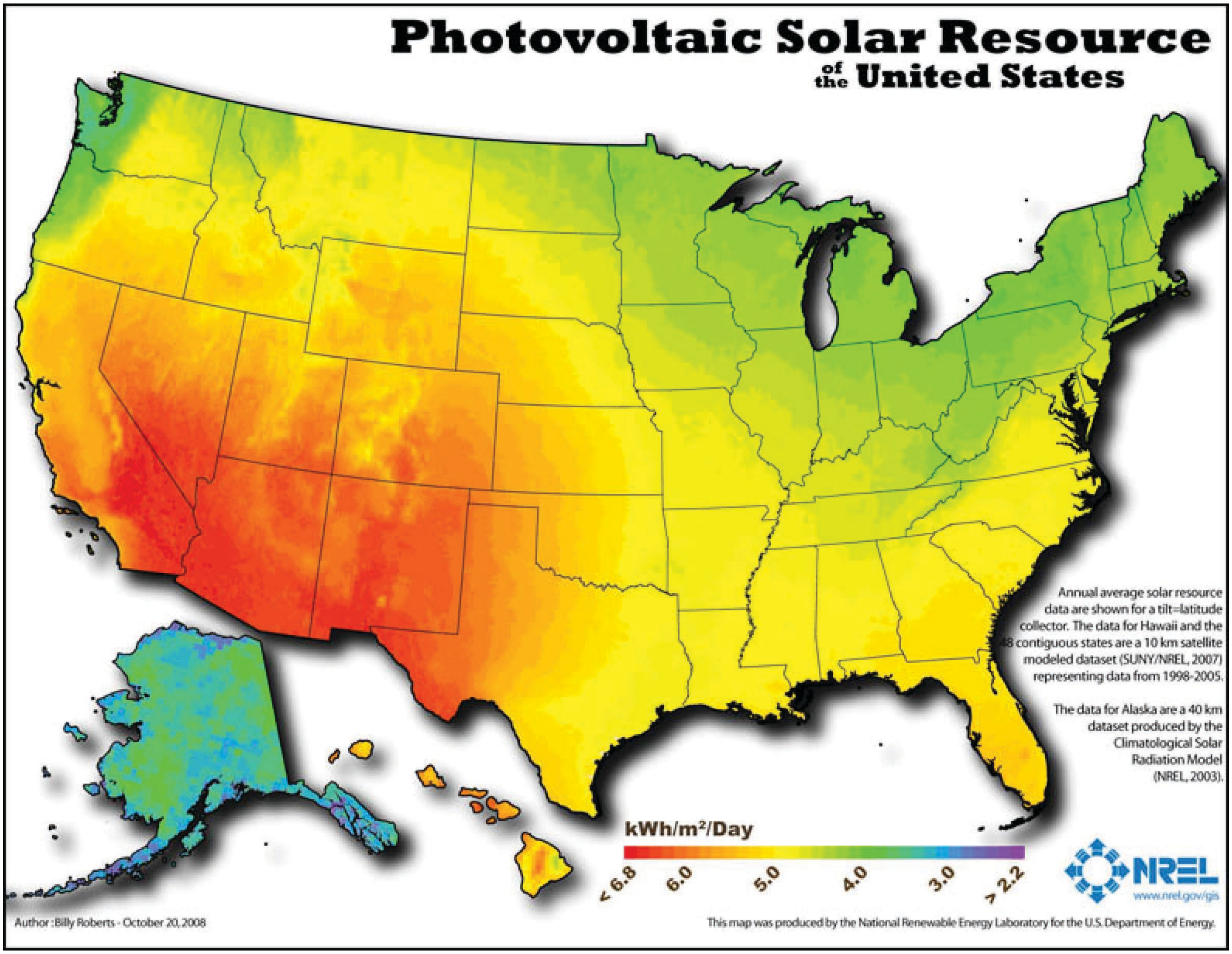
2.1.1 Physical Geography

The physical location of the airport in the United States will help determine what renewable energy technologies are viable. Some renewable energy technologies are very site specific based on the availability of the renewable resource. Others are less so. The following is a snapshot of where renewable energy resources may be viable in the United States.

2.1.1.1 Solar

Solar electricity will be produced any time the sun is shining and even under cloudy conditions. Because the sun shines everywhere, solar power can be produced anywhere. However, the amount of solar will vary based on the amount of sunshine that occurs in particular climates. Figure 2-1 shows the relative amount of solar power that can be produced by PV across the United States with the southwestern part of the country, shaded in red and orange, providing the greatest generation potential.

The amount of solar resource is a fundamental factor affecting the cost effectiveness of solar; however it is not the only factor. Other factors that can vary across the country include the availability of state incentives and strength of the demand for solar power, cost of installation, and cost of electricity. For these reasons, solar PV has been deployed quite broadly across the United States even in areas with a reduced resource potential. Conversely, concentrating solar power (CSP) constructed in large power plants requires maximum solar resources and abundant space and is primarily developed in the southwestern United States.



Source: National Renewable Energy Laboratory

Figure 2-1. Photovoltaic solar resources of the United States.

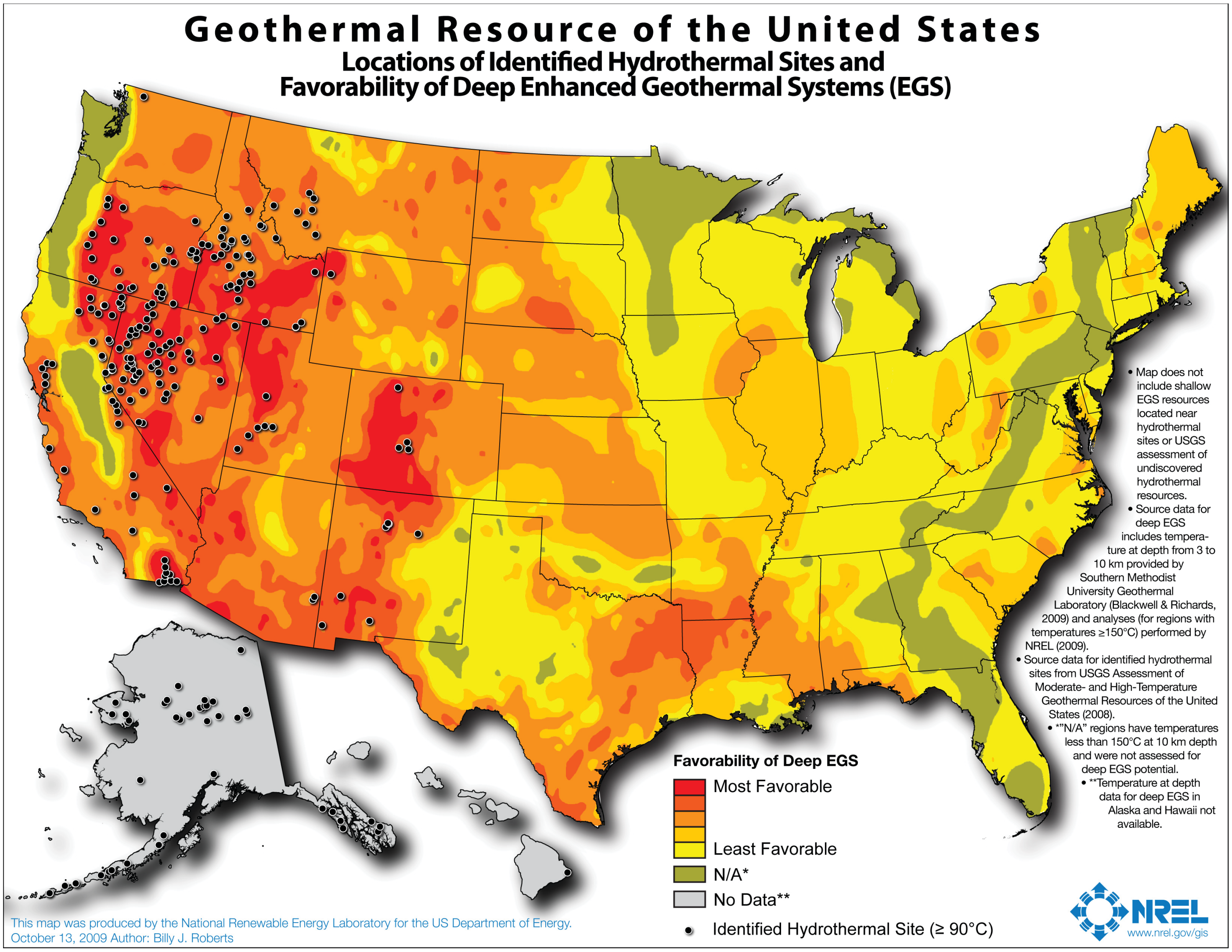
2.1.1.2 Geothermal

Geothermal resources have two diverging stories. True geothermal which taps hot spots in the earth is very site specific. Figure 2-2 shows the locations of geothermal resources in the United States with the best resource areas, shown in red and orange, occurring in the west with high concentrations in eastern California into Oregon and in Nevada and Idaho. As discussed in Chapter 1, true geothermal has primarily been developed for utility-scale electricity production in the southwestern areas of the country and is less cost-effective for airport applications.

Ground source heat pumps are not particularly geographic specific. They utilize the constant temperature and storage capacity of the earth and therefore can be located throughout the United States.

2.1.1.3 Biomass

The biomass power industry is closely affiliated with locations where organic material to fire the generation plants is locally available. For broad scale implementation, biomass fuel that is



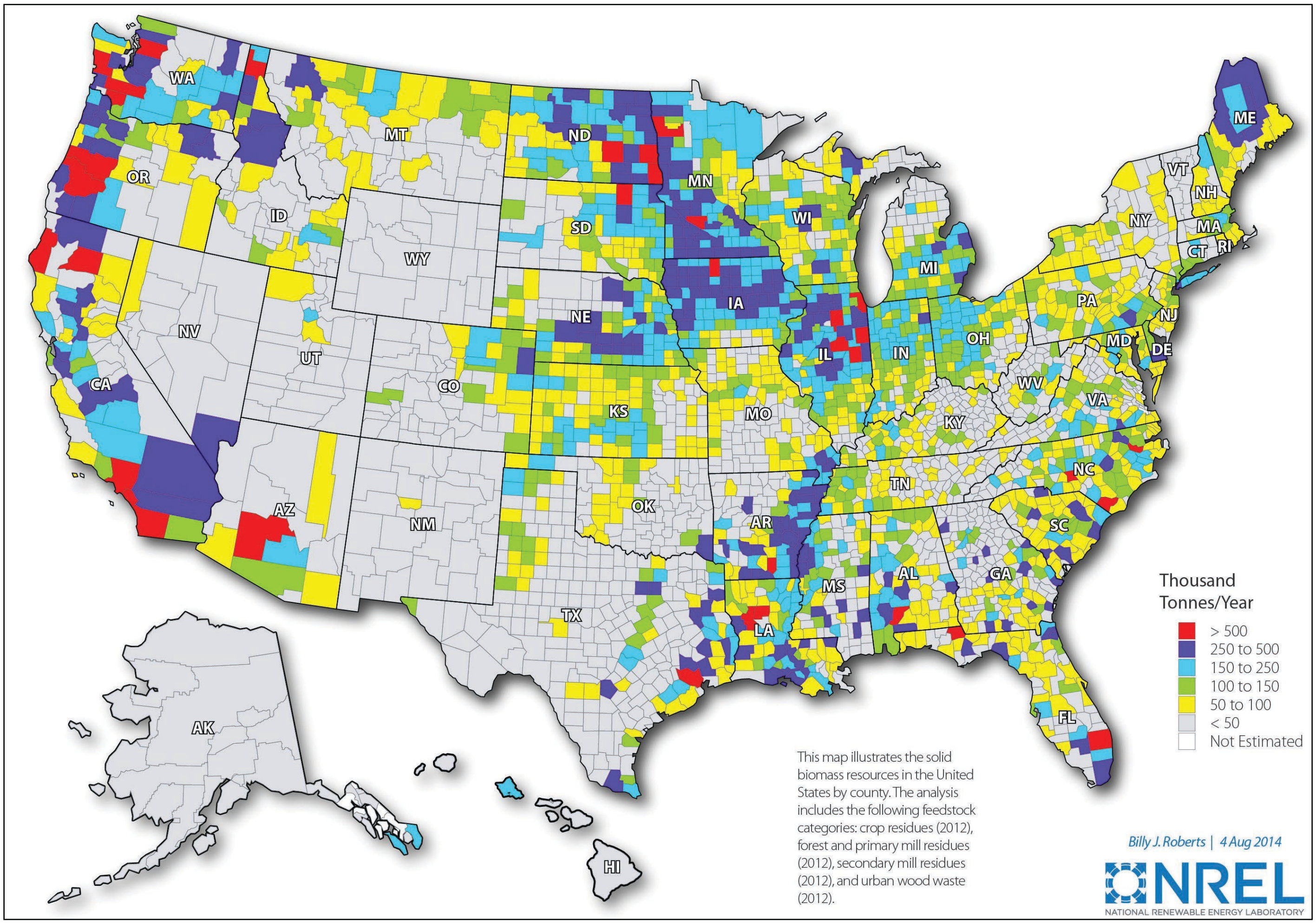
Source: National Renewable Energy Laboratory

Figure 2-2. Geothermal resource in the United States.

inexpensive enough to produce economically competitive electricity is located in areas with a timber industry and sufficient wood waste. Figure 2-3 show the availability of biomass resources, which includes wood waste, crop residue, and urban wood waste, across the United States. High concentrations of biomass depicted in red and purple are found in several different parts of the country in the west, midwest, southeast, and northeast.

2.1.1.4 Wind

Wind power generation is very site specific. For every unit of wind resource, the amount of electricity produced is cubed. This means that incremental increases in wind speed produce exponentially more electricity. Figure 2-4 shows wind resources in the United States for utility scale wind turbines. Besides the abundant wind resources in ocean waters, the best wind resource in the United States occurs in the flat plains of the midwest displayed in purple, red, and orange where there are no landscape or vegetation features to obstruct the flow of wind. High elevation areas of the Sierra, Rocky, and Appalachian Mountain ranges shown in orange and brown also have strong wind resource as well as some coastal locations, most notably in Alaska and Hawaii.



Source: National Renewable Energy Laboratory

Figure 2-3. Biomass resources in the United States by county.

2.1.1.5 Hydropower

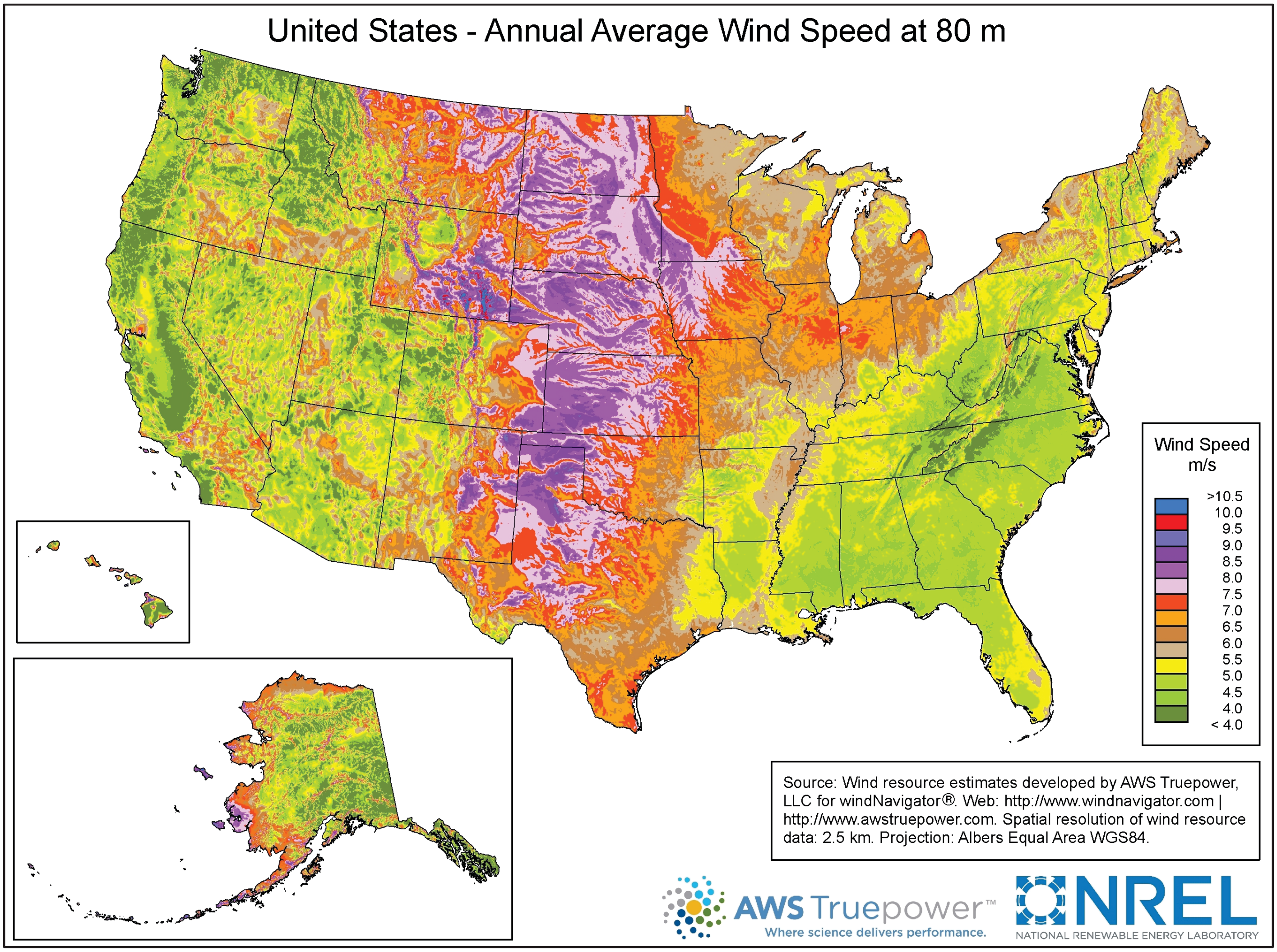
Hydropower resources are strongly correlated to relevant water features. Conventional hydropower is located along major rivers with significant changes in elevation contributing resource capacity. New run-of-the-river hydropower would be located on undammed river segments or downstream of existing dams. Tidal energy sites are specific to particular coastline features where strong currents occur and tidal range is large (i.e., northern latitudes in the United States). Wave resources are strongest on the west coast where weather patterns cross the Pacific Ocean unimpeded before coming ashore in North America.

2.1.1.6 Fuel Cells

Fuels cells are catalyzed by a fuel source that must be transported to the fuel cell. Most fuel cells today operate on natural gas and future technology is anticipated to run on hydrogen. Because fuel cells do not depend on proximity to a renewable resource, their deployment is not geographically constrained.

2.1.2 Infrastructure

Existing infrastructure networks will facilitate the development of new renewable energy projects. These networks include electric, gas, and surface transportation such as roads and



Source: National Renewable Energy Laboratory

Figure 2-4. Wind power resources in the United States.

rail. While infrastructure enhancements in association with the energy project are technically feasible, the costs associated with incremental work is likely to adversely affect the economics of a project, and therefore sufficient existing infrastructure is preferred.

2.1.2.1 Electric

All airports are connected to the electric grid by existing infrastructure which is sized to accommodate the amount of power demand from individual airport facilities. Large airports use more power and will have larger electrical infrastructure connections to the grid particularly at buildings like terminals where electricity demand is high. Smaller airports will have smaller infrastructure capacity. This highlights a potential complication with locating large renewable energy facilities on rural airports that have excess land available for leasing: the surrounding electric grid infrastructure may not be robust enough to accept power from a large renewable energy project, even off-airport, for transmission to off-site users.

2.1.2.2 Natural Gas

Natural gas pipeline networks deliver gas to airports that use it for heating needs in central heating plants. Large regional pipelines bring the pressured gas from production sources and smaller distribution networks deliver it to consumers for heating and cooking. The existing capacity of natural gas networks can influence the amount of gas that can be supplied. Where infrastructure networks are constrained, like in the northeast, natural gas prices are elevated. Availability of natural gas may also be relevant where considering the siting of a stationary fuel cell project.

2.1.2.3 Roads and Rail

Existing surface transportation networks are generally sufficient to support the construction of various renewable energy projects. The landside roadways necessary for passenger and cargo delivery are typically adequate for the type of generation and electrical equipment necessary for project construction. Wind turbine equipment with blades 150 feet long can require some specialized delivery and improvement needs should an airport be considering such an installation. However, the most significant surface transportation delivery constraint for an airport renewable energy project is related to the regular delivery and storage of biomass feedstock to run a biomass generator. Airports are typically trying to limit landside congestion to improve the passenger experience and limit environmental impacts. The regular delivery of feedstock to fuel the biomass project will increase surface transportation and could have a negative impact unless deliveries are scheduled to occur during off-peak hours.

2.2 Airport Property Characteristics

The physical attributes of the airport, its facilities and property, will have a strong bearing on what renewable energy technologies are technologically and financially feasible. Many large, urban airports consume a lot of electricity but lack open land for non-aeronautical uses. Rural airports, on the other hand, may have land available for a large development but do not have on-site electricity demand to consume the power or sufficient regional electricity distribution capacity to deliver power to other buyers on the grid. Some airports fall outside of these norms (e.g., Dallas-Fort Worth, Denver: large demand, lots of land). *ACRP Report 43* describes specific renewable energy practices at small airports (*41*). This section reviews particular airport characteristics and how they could affect selection of renewable energy technologies and project sites.

2.2.1 On-site Energy Demand

The amount of energy consumed on airport property is a fundamental factor in evaluating renewable energy projects and their business structure. Airports that consume a significant quantity of electricity may also benefit from consuming the electricity produced by the renewable energy facility. With a relative high on-site demand, the airport could serve that demand either by owning the project and off-setting demand that they had previously purchased from the electric grid or by agreeing to purchase all the power generated by the system from a third party owner.

Airports that do not consume much electricity cannot be the buyer, which limits the development options to acting as a landlord for the facility. They could own and generate electricity for use on-site; however, the amount of electricity that could be sold back to the grid during low consumption periods and the value of that electricity will vary by state and the particulars of its net metering program.

2.2.1.1 Electricity

Airports typically purchase electricity from utilities or power brokers either based on a regulated tariff rate or through contract purchasing. The electricity is supplied through a regional electric grid with customers using the supply as needed. The source of power generating electricity and the cost of the electricity varies by region and utility service territory. As an example, the northeast has become highly dependent on natural gas while the northwest receives much of its power from large hydroelectric dams and the midwest utilities utilize coal. Electricity is critical to airport operations powering operational systems, lighting, and in some cases heat and power. Typically airports do not generate any electricity on-site with the exception of some backup generators powered by diesel or oil on a short-term, emergency basis.

With long-term trends of increasing electricity costs and improvement in lighting and energy system technologies, airports have reduced electricity consumption and realized cost savings in recent years through the deployment of more energy efficient appliances such as light emitting diode (LED) lighting. These improvements have received broad support due to funding from utility rebate programs and an overall short payback period of a matter of months.

Constructing renewable electricity projects on airport property reduces the amount of electricity purchased from the electric grid. The simple payback of the investment of an airport funded system is calculated by adding up each year's annual savings in the value of the electricity generated by the system and therefore not purchased from the grid until the original investment is reached. Alternatively, an airport can purchase electricity produced by a privately owned system located on airport property and secure a relatively low and predictable price of electricity overtime that would represent an assumed cost savings when compared to the cost of traditional electricity supply that is subject to price fluctuations. Under a simplified variant, the private developer would sell the electricity to a non-airport customer and pay a lease payment to the airport—an annual source of revenue—for the right to occupy the land with a facility.

2.2.1.2 Heating and Cooling

Heating and cooling can come from a variety of systems both on and off-airport. On-site systems include central heating and cooling plants fired by oil and natural gas that is delivered by truck and pipeline. Electric heat is not cost effective at scale but may provide supplemental heating and cooling. Heating and cooling systems are strongly affected by climate and ambient weather conditions with some locations being heating dominated and others being cooling dominated.

Like electricity, costs for heating and cooling, closely tied to the cost of fossil fuels necessary to power the facilities, have been escalating in cost when considering long-term trends and vary in source and price among regions of the country. Airports have looked at opportunities to invest in such efficiency practices such as weatherization measures to minimize heating and cooling costs. Implementing co-generation projects to generate electricity and capture waste heat to heat water for heating purposes represents a systematic approach to improving energy efficiency.

Renewable thermal projects including true geothermal, ground source heat pumps and solar thermal all demonstrate options for producing heating and cooling through renewable energy sources. All renewable thermal options are on-site applications that can directly benefit the airport customer and are not readily available to off-site non-airport applications. As a result, renewable thermal projects are best configured as cost saving measures for reducing the airport's demand for off-site energy sources.

2.2.2 Real Estate

One of the airport's most valuable assets is its land and buildings. These assets support the primary aeronautical purpose of the airport. However, some of the airport's land may not be proximate enough to the existing airport infrastructure to be useful to its existing operations and future growth. Lands close to the airfield and outside of safety zones (e.g., noise buffer zones) may be suitable for renewable energy development when no other uses for the land are feasible.

Existing and proposed structures can support renewable generation and provide a ready-made platform to locate a facility.

While all airports have land and buildings, the proportion of each will vary greatly among them. Airports, both large and small, in urban areas, tend to be land constrained. If land is available, it will likely have a high value for development (unless constrained by FAA safety criteria) or may be held in reserve for airport expansion. Airports in suburban and rural areas are typically more land rich and the value of that land for alternative development decreases with land use development density.

The general characteristics of the airport provide some guidance for the types of renewable energy projects that may be most feasible based on the proportion of available land and buildings. For example, rural airports may be targeted by energy developers for large scale solar development to feed the electric grid due to a low fair market value of the land that will keep the project costs (and thus the final electricity costs) down and more competitive. Conversely, urban airports may focus on integrating renewables into new construction and major renovation projects to off-set on-site electricity costs. All airports can consider locating solar above surface parking for both energy and shelter (*42*).

2.2.3 Terrain

The terrain or land features of most airports are relatively homogenous and consistent with minimizing airspace obstructions. These characteristics include a flat and wide open landscape. However, some airports have more open and managed airport land than others. Some airports may have excess land, but it may be physically distant from airspace obstruction issues and be in a forested condition. Other airports may be adjacent to water bodies that could provide some unique renewable energy attribute.

All airports have some amount of managed airfield that must be maintained with low growing vegetation and minimal uninhabited infrastructure that is consistent with airspace safety. Beyond these areas, airports have varying amounts and qualities of neighboring lands. Any land that is presently open and not restricted from future development by proximity to safety areas is likely to be designated for aeronautical uses and reserved for future airport expansion. For site constrained airports often in densely developed areas, the only viable sites for renewable energy may be those that cannot be developed for other purposes due to limitations on site access and proximity to aircraft including lands purchased as noise buffers. In such cases, airports need to be creative in assessing opportunities and may be able to identify revenue or cost savings associated with renewable energy where few other options are available. Where land is more plentiful, siting options will be less restrictive.

2.2.4 Facilities and Vehicles

As discussed earlier, renewable energy opportunities are closely linked to the amount and types of energy consumed on airport and the potential of replacing existing energy with on-site renewable sources. Therefore it is important that the airport understand the existing energy use of the airport's facilities and vehicles to assess opportunities to utilize renewables.

All airports have similar types of facilities but at different scales. Most airports have a central building that is either a terminal supporting commercial aviation or an administrative building where the airport conducts its business. Large airports will have both. Airports also have ancillary buildings (e.g., hangars) that they own and lease out to tenants as well as buildings owned and occupied by FBO (on land owned by the airport). Airports also have aeronautical systems in the airfield that consume small amounts of electricity that may be powered remotely with renewable power.

All airports with habitable space will have on-site heating and cooling systems that draw off-site fuel for heating and electricity for cooling. Larger airports will have a central heating plant that burns natural gas or another fuel to heat multiple buildings at the airport. Landside and airside vehicles typically run on conventional gasoline and diesel though some airports are working with their tenants to convert vehicles to cleaner burning fuels including natural gas and electric.

2.3 Energy Costs

The cost of energy varies by region and is influenced by the dominant source of generation and the cost to produce the energy. This section reviews the factors that influence energy costs and the differences between conventional and renewable energy sources.

2.3.1 Conventional Electricity

Conventional electricity has been supplied by large power plants and dispatched to the regional electric grid. The electricity is generated using coal, oil, and more recently natural gas as well as nuclear. Alternative combustion fuels have been utilized in recent years including biomass and waste incineration. Smaller scale combustion variants include landfill gas and most recently fuel created by anaerobic digesters that produce methane from food waste. A strong advantage with all of these combustion sources of electricity is that they provide constant supplies of electricity to the grid (as long as the fuel supply is not interrupted) keeping the grid stable. A disadvantage of the cost of power from combustion sources is strongly linked to the price of the fuel, which can fluctuate widely based on supply and demand and is expected to increase over the long-term as the finite supplies of fossil fuels decrease. Figure 2-5 presents electricity prices by state across the United States.

In evaluating the existing cost of electricity for its PVWatts Program, the National Renewable Energy Laboratory (NREL) accesses information collected in 2012 from the U.S. Energy Information Administration (EIA) and Ventyx Research Inc. (*43*).

How much are you paying for energy today? The existing price of power is an important factor in evaluating the cost effectiveness of renewable energy. For example–a 5 kW solar PV system on the roof of your house will cost about $18,000. The average annual household consumption of electricity is 10,908 kWh. After one year, a PV system in Connecticut where the electricity price is 19.87¢/kWh would have avoided electricity purchases from the grid of $2,167 resulting in a simple payback in 8.3 years. In Washington State where the electricity price is $8.66 ¢/kWh, the simple payback is 19 years.

2.3.2 Renewable Electricity

Renewable sources of electricity have been historically dominated by hydropower which is concentrated in the eastern and western areas of the United States and is the only renewable energy source that provides uninterrupted power. Wind power technology has been advanced to the point that wind farms can produce as much power as a fossil fuel power plant though generation remains intermittent due to changing weather conditions (i.e., intermittent wind resources). In addition, some solar PV and thermal projects are being built at a scale of regional power plants but these facilities are mostly confined to the southwestern areas of the United States. Most solar PV is at a scale that provides local supply to the grid or power to primarily meet on-site demand.

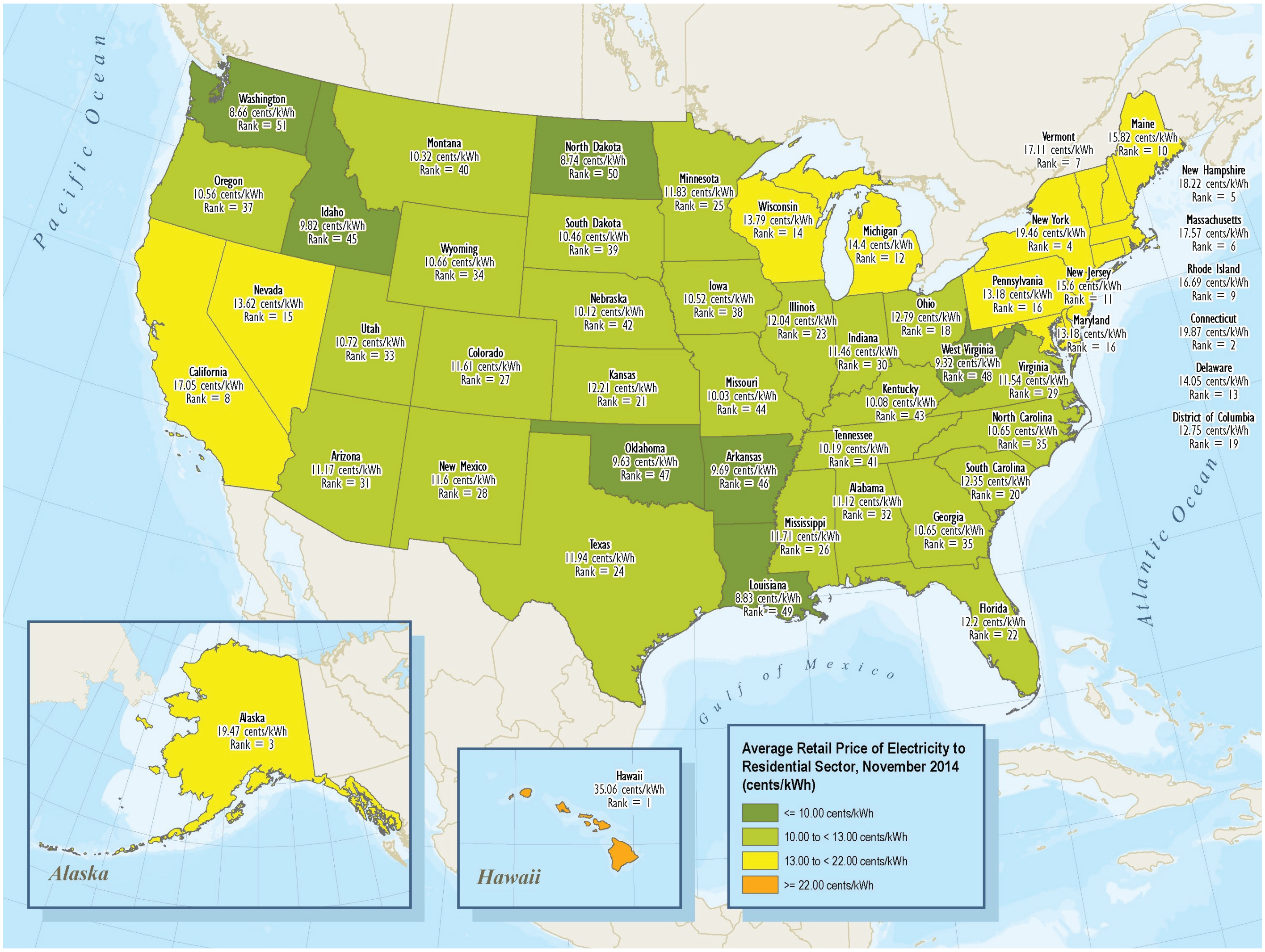


Figure 2-5. Electricity prices by state in the United States.

There are some true geothermal power plants that generate electricity for the grid but those are also localized to the southwest and western parts of the country. Other renewable technologies such as biomass, landfill gas, hydrogen, etc. are smaller in scale, providing local power.

2.3.3 Heating

Heating costs are dominated by fossil fuel sources with fuel supplied to the site and combustion occurring locally. Fuel supplies vary by regions and include oil, natural gas, propane, biomass, and electricity. Co-generation units can be coupled with existing boilers to capture and store waste heat and utilize the heated water to maximize efficiency. Renewable sources of heating are primarily limited to ground source heat pumps, solar thermal, passive solar, and renewable source electricity.

2.3.4 Cost of Power Trends

Historical analysis of the cost of power shows that energy costs have increased nationally as shown in Figure 2-6. Price also varies by region as shown in Figure 2-7. A finer scale analysis also shows that

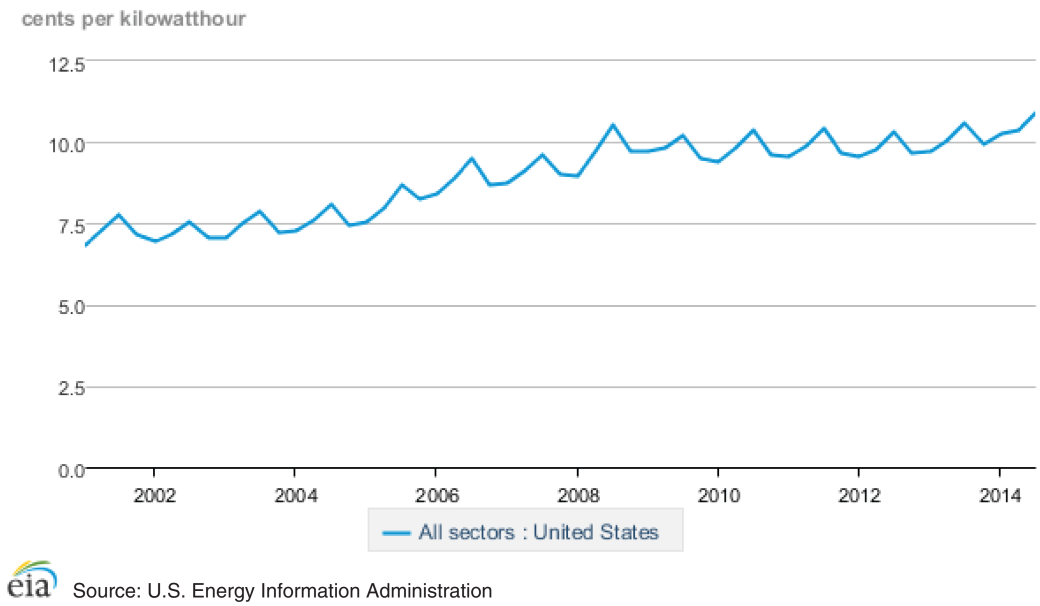
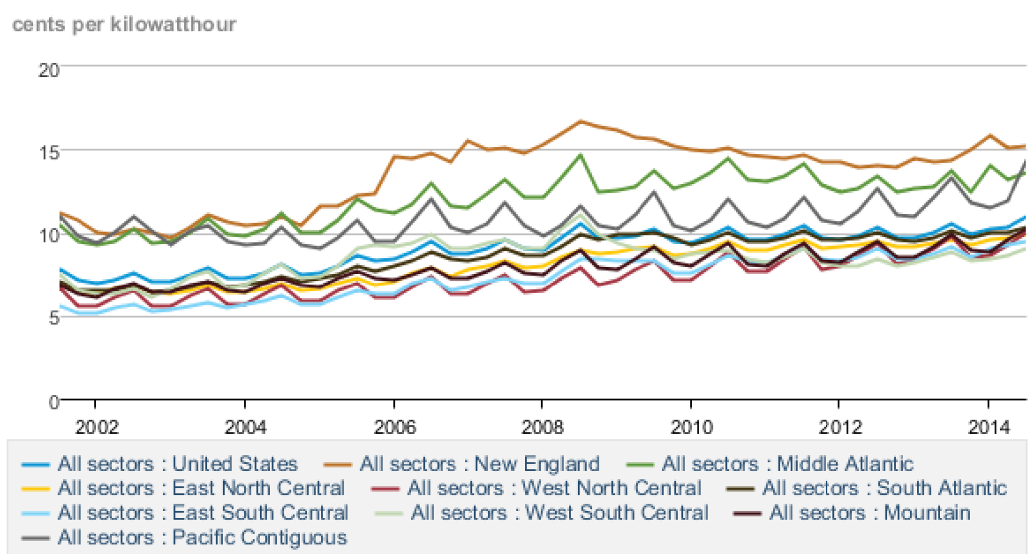


Figure 2-6. Historical power prices in the United States.

there are spikes and troughs based on short-term changes in supply and demand. A recent example of this has been the advancements in shale fracking technology that increased natural gas supply in the United States dramatically until there was a glut of natural gas and development companies ceased drilling which led to scarcities and higher prices. Demand for energy also decreases during economic slow-downs that will produce short-term price stabilization and declines.

The cost of electricity produced from renewable energy technologies has decreased significantly in recent years due to advancements in technologies and scale up of industries. This has been particularly true for wind and solar. A recent report released in September 2014 by the investment banking firm Lazard showed that the cost of solar and wind is currently cost competitive with conventional sources (*44*). Electricity produced from solar and wind (including



Data source: U.S. Energy Information Administration

Figure 2-7. Average retail price of electricity.

existing tax credit programs) on average was 5.6 cents and 1.4 cents a kilowatt hour, respectively, and compared to 6.1 cents and 6.6 cents per kilowatt hour for natural gas and coal, respectively. Without the tax credits, solar and wind was 7.2 cents and 3.7 cents, respectively. The report also showed that the levelized cost of solar had decreased by 80% over the past 5 years and wind had fallen 60% over the same timeframe. While this is good news for renewable energy advocates, solar and wind electricity generation remains intermittent unless combined with a storage capability that at this time dramatically contributes to the cost of electricity produced.

Renewable energy prices have come down: Denver Airport installed four separate solar installations between 2008 and 2014. Each was competitively bid reflecting market prices for solar at the time. The drop in price Denver paid for the electricity generated by solar from 2008 and 2014 shows how dramatically solar PV system costs have decreased. The year one price of electricity dropped by up to 45% from Solar I in 2008 to the Solar II in 2010. The potential decrease between Solar I and Solar IV (2014) is as much as 72%. See Case Summary 5.7.

2.4 Public Policy Programs

Public policy has been enacted on the federal, state, and local levels to encourage the development of the renewable energy due to its broader societal benefits. The Database of State Incentives for Renewables and Efficiency (DSIRE) is a fundamental resource in collecting up-to-date information on incentives on a geographical and technological context (*45*).

2.4.1 Tax Credits

Tax credits have been a fundamental public policy tool to incentivize many types of private sector activities that governments have sought to encourage. Congress approves tax credits for specific business sectors as part of budget authorizations and the Internal Revenue Service administers the programs and provides policy guidance on the implementation of programs.

The two types of federal tax credits that have been directed toward incentivizing the increased deployment of renewable energy technologies are the PTC and the ITC. The PTC has been applied only to wind power and awards the tax credit for each kWh of electricity produced by a wind energy facility. As a result, the developer capitalizes the project and earns the benefit once electricity is produced, thereby reducing the cost of the electricity generated. Comparatively, the ITC applies the tax credit as a percentage of the investment value or cost to construct the renewable energy facility. The ITC is most relevant to solar technologies but many other technologies are also eligible for the tax credit including fuel cells, geothermal, and tidal energy.

Authorization of tax credits by Congress has been unpredictable. It has allowed tax credit programs to expire and then be renewed for short-periods of time. This uncertainty has made it difficult for private investors to rely on the availability of the tax credits on a project-by-project basis producing inefficiencies. As of the time of this publication, the PTC for wind has expired and the current ITC benefit, notably for solar, will be reduced from 30% to 10% after December 31, 2015.

Broad scale tax credits applicable for airport renewable projects from state and local entities are rare though the interpretation of some tax laws like real estate taxes will likely have some impact on the financial costs of developing renewable energy.

2.4.2 Renewable Portfolio Standards

RPS are enacted by states to establish long-term renewable energy purchasing goals and mandate annual renewable energy purchase percentages by electric utility companies toward achieving the long-term goal. The term RPS originates from legislation proposed in California and soon after adopted by other drafters of similar state legislation (*46*).

While the design of state programs may vary, the essential idea of the RPS is the same. It requires electricity suppliers (or, alternatively, electricity generators or consumers) to source a certain quantity (in percentage, megawatt-hour, or megawatt terms) of renewable energy. They create a demand for renewable energy by necessitating its purchase or pay a penalty that is greater than any premium value for renewables established through a trading market. Many of these programs track renewable energy purchasing through the ownership of renewable energy certificates (RECs) as discussed in Section 2.4.3.

The DSIRE website provides updated information on RPS Programs. Figure 2-8 shows the current states with an RPS and those with a Renewable Portfolio Goal.

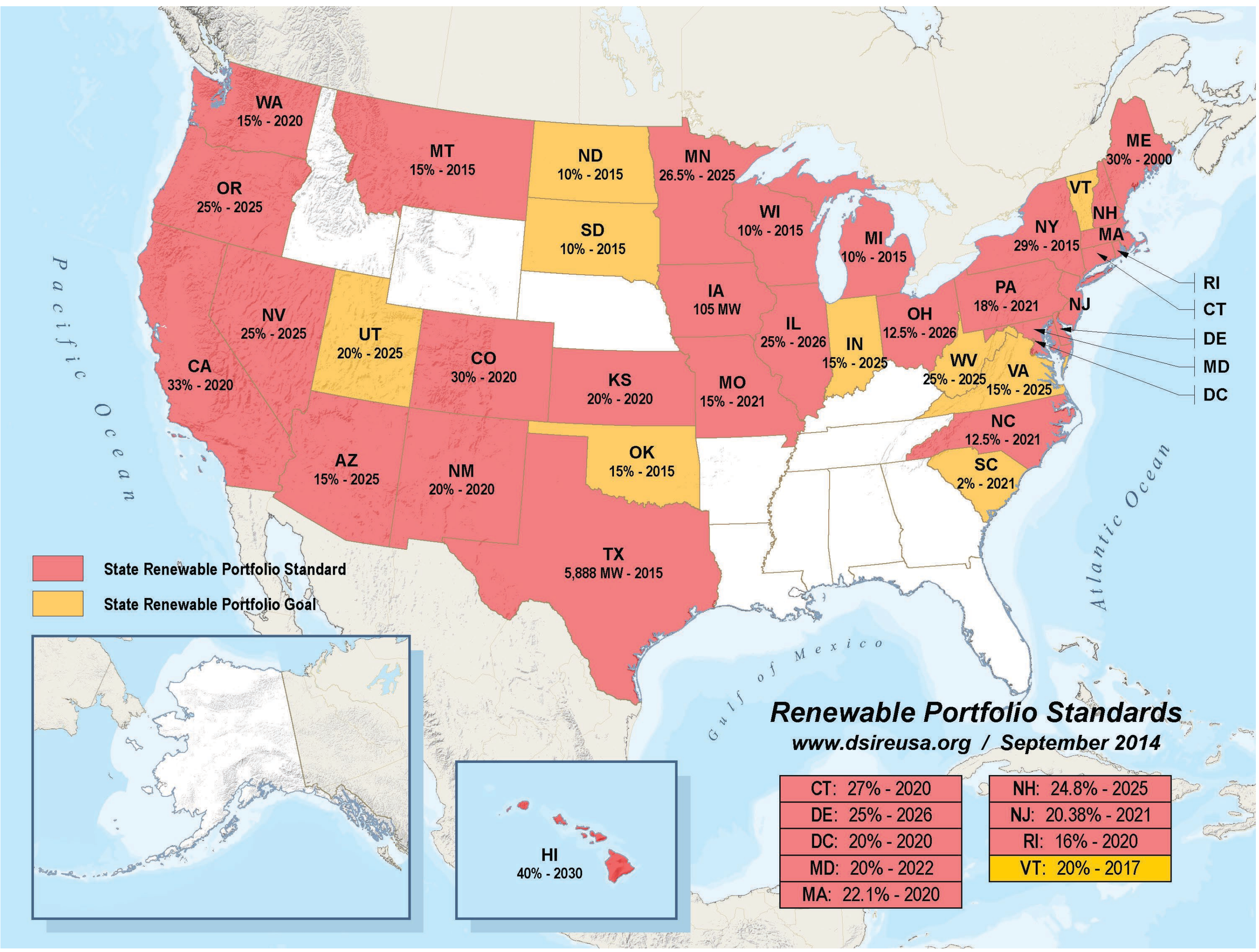


Figure 2-8. Renewable portfolio standards and goals.

RPS Drives Demand for Renewables: Denver Airport's solar projects illustrate how the Colorado Renewable Portfolio Standard (RPS) creates a demand for renewable energy. For each project, Denver International Airport (DIA) leased land to a private developer and agreed to buy the power produced by the system. However, the price it paid was equivalent to or less than traditional energy sources and not enough to fund the system costs plus investor rate of return. Therefore, the project was dependent upon securing a contract from the utility-provider, Xcel Energy, for it to acquire the RECs. In accordance with state law which established the RPS, Xcel was required to deliver to its customers a certain percentage of its total electricity from renewable sources. It issued an RFP and selected projects based on the REC price offered. In winning the bid, the third party was able to sell the RECs to Xcel providing the additional revenue stream necessary to fund the development. See Case Summary 5.7.

2.4.3 Renewable Energy Certificates

A renewable energy facility produces two distinct products: electricity and environmental attributes. The electricity product is the same as any electricity generating system as sources of electricity are not distinguishable once they are fed into the electric grid and used by customers. The value of the electricity is set by the spot market and through purchase contracts with varying terms.

The environmental attributes consist of benefits associated with avoiding emissions such as mercury and carbon dioxide (CO_2) that are produced from a conventional fossil fuel fired power plant. These environmental benefits can be packaged into a REC and sold separately from the electrical power as illustrated in Figure 2-9. RECs may also be referred to as Green

Figure 2-9. A renewable energy certificate provides additional financial value.

Tags, Renewable Energy Credits, Renewable Electricity Certificates, and Tradable Renewable Certificates. The REC is a way for regulatory entities to track buying and selling of renewable energy and credit the consumer of green power. RECs are most often sold on a per megawatt hour (MWh) basis typically through a multi-year contract.

Airports that capitalize, construct, own, and operate renewable energy facilities create RECs as the electricity is generated. The airport can hold and retire the REC and credibly claim that it uses green energy to power the airport. Or it can sell the REC as additional revenue to help pay off its initial project investment and the buyer of the REC then has claim to the renewable energy purchase. The value of the REC will vary based on the REC market.

Buyers of RECs include utilities that are required by state policy to provide a specific percentage of the total electricity for consumption from a renewable source (see renewable portfolio standards discussion in Section 2.4.2). REC buyers also include governments, private corporations, universities and hospitals that have made public commitments to purchase renewable energy as part of their corporate sustainability commitment. The list of the top consumers (both on-site generation and off-site REC purchases) of green power is listed on the U.S. EPA's Green Power Partnership website (*47*).

Who owns the green power? RECs provide a financial incentive that can be used to help fund a renewable energy project as illustrated in the case of Denver Airport. They also provide formal documentation of renewable energy utilization by the owner. An example of this comes from the San Diego County Regional Airport Authority (SDCRAA). It executed a PPA with Lindberg Field Solar 1 (LFS1) to buy the electricity from a solar installation built and owned by LFS1 at Terminal 2. As part of the PPA, SDCRAA also bought the rights to the RECs. SDCRAA wanted documentation that it owned the renewable energy attributes and provided additional compensation to LFS1 for that right. See Case Summary 5.18.

FAA guidance related to projects funded under Section 512 of the FAA Modernization and Reform Act of 2012 prohibits the airport from generating additional revenue from RECs. However, the guidance states that airports can give RECs to the utility in exchange for a discount on existing electricity bills (*48*).

In the case where the airport does not own the renewable energy system but rather leases land to a private developer to construct, own, and operate the system, the private entity also owns the RECs. The developer will want to sell both the electricity and the RECs through a long-term contract preferably to a single buyer who wants to substantiate a green energy purchase by holding and retiring the RECs. If a single buyer for both energy and RECs is not identified, these two commodities may be uncoupled and sold to two different buyers with the REC buyer being the official green power purchaser.

2.4.4 Grants

Direct government grant to airports and other renewable energy partners have had an important effect on financing project development particularly in association with the federal stimulus program and the implementation of funding under the American Recovery and Reinvestment Act (ARRA). The reader will see reference to ARRA as a component for financing a number of the case summary projects that were implemented between 2009 and 2012. ARRA funds are no longer available and its role in helping to stimulate a private renewable energy market has been served.

The FAA has also provided funding for airport owned renewable energy projects under the VALE Program, which provides discretionary funding through the AIP for emissions reduction projects. Over the past few years, the FAA has focused on ensuring the funded equipment results in a direct air emission benefit on-airport, which makes some renewable projects clearly eligible (e.g., a geothermal project replacing on-site central power plant) and others not eligible (e.g., solar PV supplying on-site electricity and replacing that provided by the grid and generated from an off-site source). This change has resulted in fewer solar projects obtaining funding under the VALE Program.

As part of the FAA Modernization and Reform Act of 2012, the FAA was authorized under Section 512 to fund energy efficiency and renewable energy projects. The FAA's shift in limiting solar funding under the VALE Program coincided with the new authority under Section 512 as a more appropriate funding mechanism. A handful of solar and geothermal projects have received funding under the program, though as of early 2015 the FAA has not yet released formal guidance on how airports can apply for the funds.

Section 3.4, Funding Sources, and Table 3-9 provide additional information on grant programs and eligibility requirements. Given the increased competition for energy and emission reduction grant funding and the uncertainty regarding availability of funding under Section 512, grants are likely the best option for airports located in states with limited renewable energy private markets.

2.4.5 Executive Orders

The executive branch of the federal government can also direct policy and department budgetary resources to effect policy. The Bush and Obama administrations both took actions that encouraged the development and purchasing of renewable energy by the federal government. Links to the Executive Orders are also found on the DSIRE website (*49*).

President Bush signed Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, on January 26, 2007 which mandated, among other things, that half of the renewable energy consumed by federal agencies in the fiscal year come from new renewable energy sources, and that agencies generate energy on-site to the extent feasible.

President Obama signed Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance on October 5, 2009 which required federal agencies to assess greenhouse gas emissions and set sustainability targets. The President issued a follow-up memorandum on December 5, 2013 which provided additional direction for federal agencies and specified that 20% of all energy consumed by federal agencies should come from renewable sources.

Under these policies, the FAA has been carrying out its responsibilities to meet the renewable energy targets under various executive orders and federal policy directives.

2.4.6 Net Metering

Net metering is a term that refers to an energy user's ability to generate on-site energy to supply its needs and export some excess energy back to the grid when it is not being used on-site. Under federal law, electric utilities must allow customers the ability to net meter, although how much compensation the generator receives and the amount that can be exported back to the electric grid varies among state programs with some being comparatively lucrative to encourage on-site generation and the ability to net meter while others are designed to discourage net metering. The concept of net metering is illustrated in Figure 2-10.

Net metering programs that are favorable to on-site generation will compensate generators at the retail electricity rate (as opposed to the wholesale rate which does not include any mark-up)

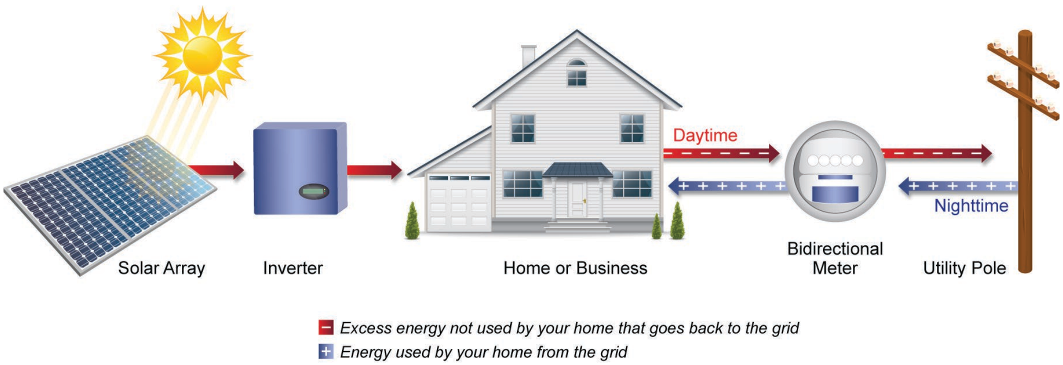


Figure 2-10. How net metering works.

allowing them to reduce their net costs by a third to a half depending on the rate structure. They may also allow for an on-site system to supply a greater percentage of power compared to the on-site demand allowing for greater revenues. Utility programs that seek to limit net metering capacity and compensate at the wholesale rate note with some justification that the export of excess electricity is utilizing the grid without paying for entry (i.e., distribution costs which are the majority of the difference between wholesale and retail prices) and thus should pay only the wholesale rate.

In cases where the on-site generation is likely not to reverse flow back to the grid because the new supply is a small percentage of the on-site demand (which might be the case at an airport), so called behind the meter projects can be quite cost effective because they limit the amount of electricity that needs to be acquired from the grid at the retail rate thereby providing the consumer with a cost savings benefit equal to the retail price of electricity. The economics of such an arrangement improves in regions of the country where the retail price of electricity is relatively high.

Matching energy generation with on-site use: Wind power is a particularly valuable resource for net metering as power generation and on-site consumption are not particularly well matched as exemplified by the case of the wind turbine at Heritage Aviation in Burlington, VT. While a 24/7 operation, Heritage's on-site electricity consumption is similar to most workplace environments with demand high during the day and low at night. Wind energy generation follows some seasonal and daily patterns but is more influenced by episodic weather fronts which can occur at any time of day. For Heritage, it draws electricity from the wind turbine when needed, but the power is also exported to the grid when on-site demand is low, like in the middle of the night. Heritage is paid for the electricity it supplies to the grid. Likewise, when the wind is not blowing, Heritage can take what it needs from the grid. Balanced out, Heritage gets financial value for all of the electricity produced by the wind turbine as a result of net metering policy.

2.4.7 Power Purchase Agreements

The PPA, also referred to as a long-term contract, is generally the central and most important document in a third party owned renewable energy project because from it is where the majority of the revenue for a project is derived. PPAs are contracts that establish a commitment to purchase power at a specific price over a specific term. PPAs are critical for privately financed power deals because they guarantee an annual revenue stream for the repayment of investors. The buyer of the electricity locks in a price for the electricity over a defined future period that provides known and stable electricity prices and also a hedge against volatile market prices that are forecast to increase in the future. While future prices are not known today, the year one price is often set at or below existing prices. Any time in the future when market prices exceed the PPA price, the electricity buyer will enjoy the differential as a cost savings. The potential downside for the airport is that short-term energy prices could go down below the PPA price. This is a risk to the airport in committing to the PPA; however, prior to committing to a PPA an evaluation of historical energy costs should be evaluated along with future energy prices that are forecast to increase. Therefore, there is strong evidence to suggest energy costs will continue to rise and evaluating PPAs is still very attractive for airports from a business perspective.

PPAs may also be issued in response to a so-called Feed-In Tariff or FIT. The FIT is a public procurement for energy that sets a price that will be paid by the utility for the energy. The FIT price varies by technology and reflects the actual cost of energy produced by a facility after all development costs and specified investment returns are factored in. FIT programs have been more widespread in Europe whereas U.S. policies have relied on tax credits and RPS mandates that utilize market approaches to calculate the cost of energy.

One item particular to renewable energy projects is that the revenue stream for a project often consists of two distinct commodities that may be sold together or separately. These two commodities are energy and environmental attributes. These environmental attributes are some form of a renewable energy certificate (see Section 2.4.3). Environmental attributes may be an important revenue stream for a renewable project. Thus, it is important to note whether a PPA includes or excludes the sale of RECs with the power. A bundled PPA is one in which the seller is selling both the power and the environmental attributes, while an unbundled PPA includes sale of only the power. In an unbundled PPA, the developer may sell the RECs to a different purchaser under a REC contract.

Indianapolis as an example: Indianapolis Power & Light (IPL) uses its Rate Renewable Energy Production (REP) program as a means of purchasing renewable energy. The program operates like a feed-in tariff where IPL purchases the output through long-term contracts at a fixed rate. The minimum size of an eligible solar array is 20 kW and no larger than 10 MW. Solar generators receive $0.24 per kWh for facilities between 20 and 100 kW and $0.20 for solar arrays larger than 100 kW. Johnson Melloh Solutions, the third party owner of the solar farm at Indianapolis International Airport, obtained long-term contracts for two 12.5 MW Projects that are currently operating. See Case Summary 5.10.

2.5 Ownership and Operational Arrangements

There are three primary ownership scenarios for airport renewable energy projects. They are airport owned, third party owned with airport as host, and third party owned with airport as power purchaser (*50*). Other lesser arrangements are airport owned with an equipment lease, utility owned with airport as host, and tenant-owned.

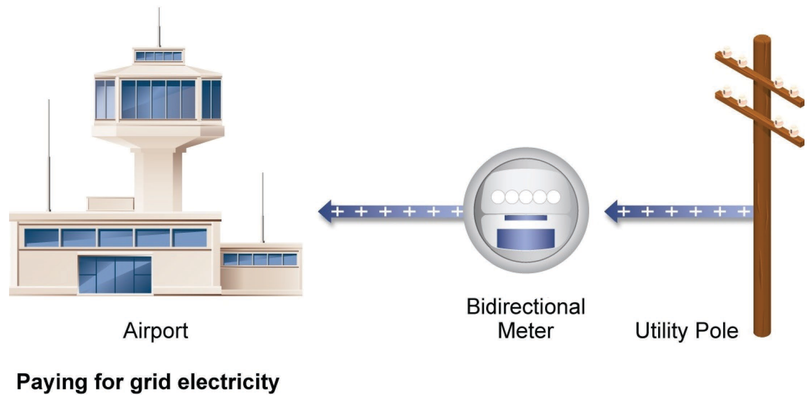


Figure 2-11. Typical condition when airport buys electricity from the grid.

2.5.1 Airport Owned

Under existing conditions, the airport purchases electricity from the utility drawing on the grid as demand warrants. The utility sends the airport a monthly bill for the electricity it uses based on an accounting at the utilities electrical meter. This is illustrated in Figure 2-11.

If the airport funded, constructed, owned and operated its own renewable energy facility, it would generate electricity from the system on-site and behind the meter. At times when the system generates more electricity than the building can consume, the excess electricity is sold back to the utility. At times when the building consumes more electricity than the system can produce, the airport purchases the required electricity from the utility. The meter records the amount of electricity draw from the grid and credits back excess electricity sold to the utility. This is known as net metering. The amount of electricity that can be sold and the value of that electricity (e.g., wholesale or retail rate) varies among states. However, the difference between what is bought and sold is the airport's electricity bill (which could be a liability or an asset). This process is illustrated in Figure 2-12.

The same general process can also occur when an airport installs an on-site heating system (e.g., ground source heat pump) that limits the amount of need for traditional fuel (e.g., natural gas) for heating purposes.

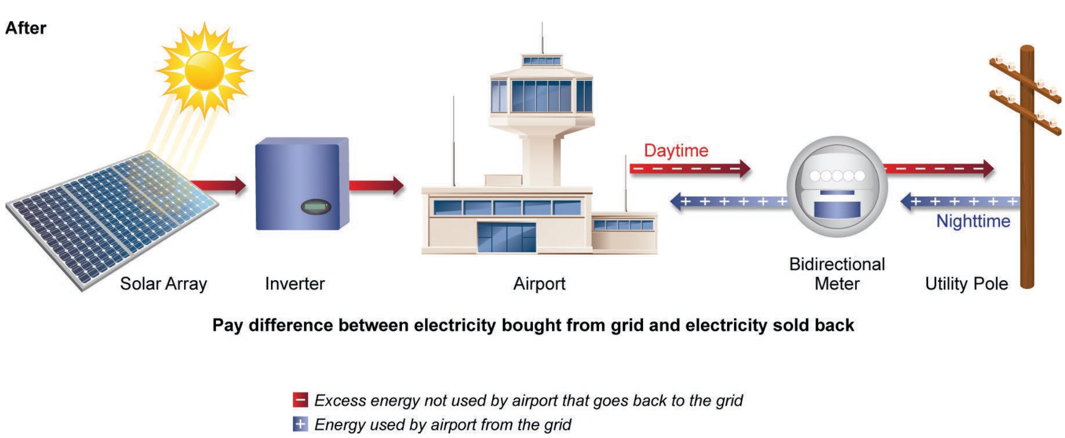


Figure 2-12. Airport owned renewable energy system.

2.5.2 Third Party Owned–Airport Host

In a third party owned project, the airport leases out property (land or building) to a private developer who will construct, own, and operate the facility under a long-term lease agreement. Third party owned projects are particularly attractive in states where there is a strong solar power market and private entities are actively looking for development sites and green power purchasers. In these situations, development companies profit from solar developments primarily due to the ability to monetize the federal investment tax credit that is currently equal to 30% of the project installation cost, and a state market for renewable energy which directs utilities to purchase green power at a premium price.

In the case where there is a third party owner and the airport is the host, the third party simply pays the airport an annual land lease payment for the right to operate the facility and it sells the power generated by the facility to an off-site customer. These agreements typically work where the fair market value of the land is relatively low and can be absorbed into the project finances while keeping the electricity price at a competitive level. The airport will continue to receive its electricity as it always has as illustrated in Figure 2-11. The third party will produce power and send it onto the grid and an off-site party will execute a PPA with the third party to acquire the electricity and the renewable energy certificates that are created by the generation of green power.

2.5.3 Third Party Owned–Airport as Power Purchaser

In this variant, the project is structured as described earlier with the airport providing a long-term lease to a private entity to construct, own, and operate the facility. However, in this arrangement, the airport also executes a PPA which is a contract for the airport to purchase all of the power produced for a long-term period (usually 15 to 25 years) at specified annual rates. The PPA is a critical aspect of project financing because it guarantees a long-term revenue stream during facility operation that assures that investors will receive a return on their investment based on the established PPA price of electricity. The third party is particularly interested in developing renewable energy projects at airports because airports are a credit worthy long-term purchaser of energy. Figure 2-13 shows that the power is purchased by the airport to meet a portion of its demand and purchasing the remainder of the power from the electric grid.

PPAs provide airports with two benefits: one that is assured; the other that is assumed. By purchasing power for the next 15–25 years, the airport is assured that its price of power will be stable and predictable. The primary benefit is that the PPA provides cost certainty and is a hedge or an insurance policy against episodic price volatility and long-term significant price increases.

Figure 2-13. Third party owned with airport purchasing the system power.

It is not a guarantee of long-term cost savings because the future price of electricity is not known. We know that electricity prices in the United States have increased 50% since 2002 as shown in Figure 2-6. Based on this history, it is assumed that prices will continue to increase and forecasts from the EIA predict electricity prices will increase annually by 0.4% over the next 10 years. However, there is no guarantee that this will occur.

In its Interim Guidance on Energy Efficiency for projects that receive FAA funding under Section 512 of the Modernization and Reform Act of 2012, the FAA has added requirements associated with PPAs (*51*), specifically:

- Does not include penalties should the solar system not produce a minimum level of power;
- Reflects market rates for the electricity sold to the local utility provider;
- Is either revenue neutral or financially net beneficial to the airport sponsor on an annual basis meaning the airport must receive at least as much financial benefit annually as the fair market value of the electricity sold.

While third party (privately-owned) projects with PPAs are unlikely to require or demonstrate a need for FAA funding to the airport sponsor, it is possible that the FAA may seek to impose these requirements through its broader authority under grant assurances in approving ground leases.

2.5.4 Airport Owned Equipment with Private Lease

One of the advantages of the third party owned structures is that the third party can monetize the tax benefits associated with the investment tax credit that cannot be accomplished by a non-tax paying entity like a government agency or non-profit organization. The savings associated with monetizing the tax credits can then be shared with the project partners through a lower power cost and lease payments as relevant.

In this arrangement, the airport owns the project but leases the equipment from a private entity, which can also monetize the tax credits and pass those savings on to the airport in reduced lease payments. The airport owns the system and therefore reduces the amount of power it purchases from the grid as with the airport owned scenario discussed in Section 2.5.1. The benefit is that the airport does not need to capitalize the cost of the renewable energy facility equipment, only the installation cost, thereby reducing the overall installation costs compared with the conventional airport owned scenario. The trade-off is that it has the additional lease payment to make to the equipment holder and it will eventually make an investment to buy the equipment outright once the leasing company fully monetizes the tax benefits after year 6.

> Redding Municipal Airport in California structured its solar project as airport owned but with the equipment leased. This unique structure allows the airport to own the facility, yet work with a private leasing company that can qualify for tax credits and pass the savings on to the airport. See Case Summary 5.16.

2.5.5 Utility Owned with Airport Host

Depending on how utilities are regulated within a state, utility companies may be owners of energy generation projects. The most common owners are utilities that are owned and operated as part of the municipal government. It is generally feasible for a utility company to own a renewable energy generation facility that is sited on airport property. This type of arrangement is

Source: San Francisco International Airport

The 450 kW roof-mounted solar facility on the roof of Terminal 3 at San Francisco International Airport (SFO) is owned and operated by the San Francisco Public Utility Commission (SFPUC), which is responsible for providing power for municipal facilities and its customers. The SFPUC identified 19 municipal facilities for solar installations including SFO Terminal. It builds, owns, operates, and maintains these facilities to provide a solar product to its customers. Because the price of solar electricity is socialized across all system users, the airport pays the same rate for electricity used at all its meters.

Figure 2-14. Solar array at San Francisco Terminal 3.

more likely where the utility is owned by the municipality and generation sites for utility owned facilities are located on municipal property including the airport. Such an example of an airport solar project owned and operated by the municipal utility is in Figure 2-14.

Where renewable energy generation is constructed, owned, and operated by the municipal utility on airport property, the utility and the airport likely have considerable flexibility in structuring the arrangement. The airport may just act as a host and pay its electric bills without any change as hosting the project particularly on a building rooftop that is not utilized for other purposes does not present a cost that needs to be off-set. In other cases, the airport may receive a reduced energy bill from the utility based on the output of the renewable energy facility.

The municipal utility will develop such projects to provide its customers with a green power electricity mix, diversify its electricity supply sources, and provide a potential long-term savings from renewable energy. Irrespective of the compensation agreement with the utility, the airport will obtain ancillary benefits associated with public exposure that the airport is generating green power.

2.5.6 Tenant Owned

Airport tenants may seek to construct renewable energy projects on property or buildings owned or leased on airport property. As the tenant executes a contract to lease airport property, which contains the specific terms and conditions of the lease arrangement, the airport has considerable control over what the tenant can do and any compensation.

Renewable energy projects at tenant owned facilities are most common when new hangars and buildings are constructed. In some cases, the tenant includes the renewable energy project as part of an airport requirement that the new structure meet a sustainability standard typically communicated in airport policy associated with new construction. While renewable energy may not be specifically required, projects are often directed to meet a Leadership in Energy and Environmental Design (LEED) standard and on-site renewable energy generation may be one of the options that could be employed to help achieve the required standard.

Because tenants typically pay their own electricity bills, the installation of a renewable energy project to off-set power purchased from the grid does not inherently provide a financial benefit to the airport. Airports could impose a fee for allowing the renewable energy system that does not adversely affect the project economics but provides the airport with a modest revenue source. However, airports that have a sustainability requirement on tenants may not be able to justify profiting from the requirement by adding a surcharge.

There are a few tenant-owned renewable energy systems discussed in the case summaries (see BTV 5.5 and SAN 5.17). In each case, the airport supported the tenant's pursuit of renewable energy but does not receive a specific financial benefit from the installations.

2.5.7 Community Solar

Shared renewable energy arrangements allow several energy customers to share the benefits of one local renewable energy power plant. When the power is supplied strictly by solar energy, it is sometimes called community solar. The shared renewables project pools investments from multiple members of a community and provides power and/or financial benefits in return. There are several different models for ownership including (1) utility-owned to provide a green product to their customers, (2) member-owned where a special purpose entity (SPE) builds and owns the facility and provides power to members or subscribers, and (3) nonprofit owned where donors fund the system. Figure 2-15 shows the opening of a community solar project located at Garfield County Airport in Rifle, Colorado.

2.6 Regulatory and Compliance Requirements

Airports will need to assess the regulatory requirements and identify any permitting challenges early in project planning as part of site selection and alternatives analysis. Particular sites may harbor sensitive resources or have a potential effect on airspace and require enhanced analysis and mitigation that could be costly and time consuming. These issues need to be considered early on in project development. The following section summarizes relevant primary regulatory issues.

2.6.1 National Environmental Policy Act Review

The National Environmental Policy Act (NEPA) requires federal agencies to evaluate the environmental impacts of their actions and consider alternatives to mitigate potential impacts.

Source: Garfield County Colorado

In June 2011, the Clean Energy Collective (CEC), a private renewable energy company, completed installation of a 858 kW community owned solar project at Garfield County Airport. The CEC leases the ground at the airport from Garfield County for the array. Its members/owners receive energy savings through a power purchase agreement with their serving utilities. The $5.1 million array contains 3,600 photovoltaic solar panels and occupies about five acres of county leased land.

Figure 2-15. Community solar project in Colorado.

For all new projects at airports that require a federal action, a NEPA review must be conducted. Federal actions can include a change to the ALP, the issuance of a federal permit or approval, or the granting of federal funds.

New airport structures would likely trigger an update to the ALP and therefore require environmental review under NEPA. However, a determination issued by the FAA under an airspace review is not considered a federal action and alone does not trigger a NEPA review. Any renewable energy project must be reviewed under NEPA if (1) the airport receives federal funding or (2) there is a lease to a private third party.

Sponsors and their partners file information on the project with the FAA to initiate their NEPA reviews. Sponsors of projects that are deemed to have a *de minimus* impact may file a form requesting a categorical exclusion or CATEX. Sponsors of projects that have greater impacts must file additional information on the project and the anticipated environmental impacts in the form of an Environmental Assessment or EA. The FAA may determine that the level of information submitted in the EA is not enough to adequately characterize impacts and prescribe mitigation and require the submission of a more detailed analysis as part of an Environmental Impact Statement or EIS.

Solar PV projects previously reviewed under NEPA have received a CATEX. After consulting with the region or airport district office (ADO) about the project and environmental issues, the sponsor will provide the FAA with environmental information to support a CATEX or EA. Past solar PV projects have received a CATEX from the region or ADO, supported by background documentation on the purpose and need for the project and any potential environmental impacts. Once the appropriate NEPA documentation is provided, the FAA will issue a Finding of No Significant Impacts (FONSI) concluding its responsibility under NEPA.

The Draft FAA Order 1050.1F includes a specific CATEX for solar and wind power (*52*). It reads as follows:

> Approval of an Airport Layout Plan (ALP), Federal financial assistance for, or FAA projects for: the installation of solar or wind-powered energy equipment, provided the installation does not involve more than three total acres of land (including the land needed for easements and rights-of-way associated with building and installing the equipment, and any trenching and cabling that would connect the installed solar or wind equipment to other parts of the airport or an existing electrical grid. Construction contracts or leases for this equipment must include requirements to control dust, sedimentation, storm water, and accidental spills).

This CATEX provides additional direction to ADO's for considering a CATEX for solar whereas past projects obtained a CATEX under designations associated with (1) minor expansions of existing facilities, (2) purchase, lease or acquisition of three acres or less of land, or (3) upgrading of building electrical systems.

2.6.2 Environmental Resources

While renewable energy projects typically do not release any emissions (with the exception of biomass) or store any hazardous materials, potential environmental damage is limited to impacts associated with land development. Still, project sites may provide environmental benefits that are subject to regulatory review (see FAA Order 5050.4). The following natural resource impacts are among the areas that should be considered during a NEPA review and may require individual federal, state, or local permits.

2.6.2.1 Wildlife Habitat / Endangered Species

Wildlife habitat on airports typically includes habitats for species that prefer a grassland environment. While the airfield environment is managed to be free of natural groundcover, shrubs, trees, and water bodies that provide structure for shelter, foraging, and reproduction of wildlife, it can attract a specific group of animals. Species that had to be considered during siting and design of past projects include burrowing owl, kit fox, and grassland birds. Some of these species may be listed for protection under federal or state endangered species laws. Should the airport decide to proceed with a project at a site where wildlife habitat may be impacted, the sponsor will need to characterize the extent of the habitat, demonstrate how the project will minimize impacts, and mitigate for any unavoidable damage.

2.6.2.2 Water Quality Impacts from Erosion and Sedimentation

Construction projects disturb vegetation and soil and make it available to erosion caused by rain events. The footprint of land disturbance for solar projects is limited to posts that hold up the ground-mounted panels. However, construction vehicles needed to bring the panels and other materials to the site and install the equipment can cause temporary impacts on the land that must be managed to avoid erosion and sedimentation. The potential environmental impacts of erosion will vary considerably by region depending on the time necessary to re-vegetate and stabilize disturbed areas. As an example, two years after construction of its Pena Boulevard Solar Project, DIA continues to maintain erosion control and actively re-vegetate lands disturbed by construction.

2.6.2.3 Wetlands Disturbance

Wetlands are protected by federal and state environmental laws due to their broad benefits to wildlife and water quality. Projects that disturb wetlands or are proposed near wetlands may require the issuance of a wetland permit. The permit may require land stabilization to prevent against erosion and sedimentation. It may also require an assessment of alternatives to avoid and minimize impacts, and measures to mitigate unavoidable impacts. For Denver's Pena Boulevard

Project, the developer connected two sections of the project by drilling and installing a cable underneath a wetland to avoid a physical impact from traditional trenching.

2.6.2.4 Cultural Resources

Federal activities must comply with the National Historic Preservation Act. Many states also have historic preservation programs that may encompass additional areas. Solar projects proposed for the roofs of historic airport buildings may require approval to ensure that the solar panels do not adversely impact the historic value of the structure. Ground-mounted projects that disturb soils may need to conduct an archaeological study to ensure that below-ground historic resources are not impacted.

2.6.2.5 Hazardous Materials

Hazardous materials are regulated by federal and state laws. Because solar panels do not employ hazardous materials, the use of them does not trigger an environmental review. However, if a project is proposing to disturb land to construct a solar facility, the applicant may need to test the soil prior to any work to ensure that historic contamination is not released from the soil. Should preliminary testing suggest that soils may be contaminated with a regulated waste, it may be wise to avoid construction in that area for both environmental and economic reasons.

2.6.3 Local Zoning

If an airport is subject to local zoning laws, development of a renewable energy facility at the airport may require that the developer obtain a variance under the zoning code. However, many state and local governments have adopted laws and ordinances that simplify the zoning permitting process for certain types of renewable energy facilities.

2.6.4 Airspace Safety Review

The FAA's Obstruction Evaluation / Airport Airspace Analysis (OE/AAA) Division undertakes aeronautical studies to assess the potential impacts of a project on air navigation. It distributes the notice to representatives of the various FAA lines of business, including airports, technical operations, services, frequency management, flight standards, flight procedures office, and military representatives. Each division has the responsibility of providing comment on the potential impacts of a proposal on its area of authority and expertise. As an example, air traffic personnel is responsible for identifying whether the structure impinges on airspace; assessing effect on existing and proposed aeronautic operations, traffic control procedures, and traffic patterns; providing comment on mitigation opportunities including marking/lighting; identifying when negotiations with sponsors are necessary; determining when circulation is necessary and coordinating that process; collecting all comments; and issuing the determination. Technical Operations staff identifies electromagnetic and/or physical effects including the effect of sunlight and reflections on air navigation and communication facilities.

Upon completing the aeronautical study and obtaining input from the various divisions and organizations involved in the review, the OE/AAA issues a determination on the proposed structure or activity. If the project will not impact aviation, the OE/AAA will issue a Determination of No Hazard. If an impact is identified, the OE/AAA will issue a Determination of Presumed Hazard, the reason for the hazard, and changes that could be made to avoid the hazard. Unless the applicant agrees to the changes in writing, the Notice of Presumed Hazard will be re-issued as a Determination of Hazard as the FAA's final determination on the matter. The determination, however, is not a permit enforceable by law but is instead part of a notification process to identify potential hazards to aviation, require marking and lighting of potential hazards to minimize potential risk to aviation, and update aeronautical charts and flight procedures for pilots to avoid the hazard. In reality, however, a hazard determination is sufficient enough to deter project financing and underwriting due to the potential liability associated with the determination. As an example, most utility-scale wind turbines rise greater than 200 feet above the ground and are subject to airspace review by the OE/AAA. The receipt of a hazard determination from the FAA for a proposed wind turbine is considered by project developers to be a fatal flaw thereby negating the project.

Potential impacts of energy projects on aviation were reviewed in detail in *ACRP Report 108: Guidebook for Energy Facilities Compatibility with Airports and Airspace.* The following section provides a brief summary of the primary issues discussed in that report that are relevant to on-site renewable energy generation projects.

2.6.4.1 Physical Obstructions

The FAA is responsible for guarding the National Airspace System (NAS) against intrusions that may impede safe use of airspace and airport resources. The FAA regulates such intrusions as obstructions (physical) or aviation safety hazards (non-physical). The FAA's ability to regulate obstruction intrusions into the NAS is extremely limited, as it is restricted to monitoring the erection of obstructions (i.e., charting) and mitigating hazards by modifying aviation procedures. The FAA's ability to enforce on-airport land use is based entirely on contractually based grant assurances, rather than regulations. However, off-airport land use regulations are largely at the discretion of local government.

One of the primary means of protecting airspace on airport property, where the FAA has jurisdiction, is through the preparation of ALPs and Master Plans. The FAA and airports utilize Advisory Circular (AC) 150-5300-13A, Airport Design, to guide development on airport property and prepare the ALPs. For land uses off airport property, the FAA works with airports and their local communities to achieve conformance of existing and proposed natural and developed features to airspace protection criteria. Because protection criteria is well-defined for physical penetrations of airspace and less so for non-physical impacts, the criteria and guidance for land use planning can vary among project types.

The following are examples of legislative and regulatory guidance to protect airspace and airport resources from unsafe intrusion:

- Runway Protection Zones, as defined by FAA AC 150-5300-13A, Airport Design
- Obstruction Height Zones, as defined by 14 CFR Part 77 and local zoning ordinances
- The United States Standard for Terminal Instrument Procedures (TERPS), as defined by FAA Order 8260.3B
- Land use controls, as defined by local zoning ordinances (new Land Use Compatibility, AC 150/5190-4A)

All energy technologies (and other structures for that matter) have the potential to penetrate airspace depending on proximity to airports. However, any structure rising more than 200 feet above existing ground elevation penetrates the imaginary surfaces that define airspace and requires notification with the FAA. Utility-scale wind turbines currently in design and construction are 400 feet or taller while CSP towers can also be over 400 feet. For other structures under 200 feet, a physical penetration to airspace could occur when the structure is located in relatively close proximity to an airport. These projects are reviewed by FAA under 14 CFR Part 77 and a determination is made on a case by case basis. The structural nature of energy technologies helps to define their potential to be compatible with airports and airspace. For example, large wind turbines are difficult to site near airports while low profile solar panels typically can be located so as to not penetrate the imaginary surfaces as illustrated in Figure 2-16.

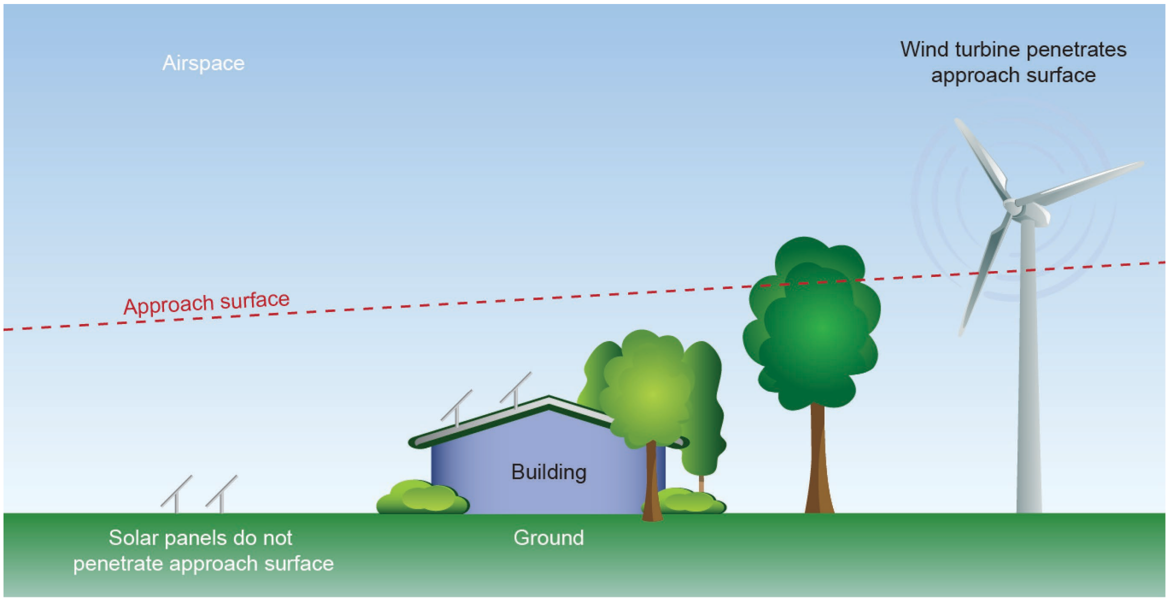


Figure 2-16. Examples of structures that may impinge on airspace.

2.6.4.2 Solar Glare

Glare is produced when light from a source or reflected from a surface impairs a receptor's view. Glare impacts are assessed based on the sun's position, the potential for a surface area to reflect light, and the sensitivity of a receptor to observe the glare. Sensitive receptors at airports include the air traffic control tower (ATCT) cab and aircraft on approach. Figure 2-17 illustrates how glare can interact with a sensitive receptor based on the movement of the sun.

Impacts of glare in the energy sector have been primarily associated with solar power facilities including PV panels and CSP systems. Glare impacts from CSP systems are expected, as they use mirrors at centralized power plants, but glare impacts from PV installations may be unexpected, as they produce electricity by absorbing (rather than reflecting) sunlight. Solar PV is commonly being located on airport property to provide cost savings and produce alternative revenue for the airport. However, their close proximity to sensitive airport receptors such as the air traffic controllers and pilots on final approach has been verified as producing potential glare effects.

Understanding of the potential impact of solar glare on airport sensitive receptors has expanded significantly over a short amount of time. When the FAA released "Technical Guidance for Selected Solar Technologies at Airports" in November 2010, there were fewer solar projects at airports compared to today and no reports of glare impacts. Glare was assessed primarily in a qualitative fashion and the authors recommended the development of modeling tools to better address the issue. Eighteen months later, the glare incident at Manchester-Boston Regional Airport (MHT) focused the FAA's attention on the potential safety concerns and within 6 months, a modeling tool was developed (*53*). Appropriate use of Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) and coordination with the FAA will likely make siting and impact analysis more efficient and accelerate the approval of future solar projects. Additionally, while low-glare glass may not be an explicit project requirement, airports considering solar projects should request feasibility assessments for use of low-glare glass to mitigate glare in the requests for proposal (i.e., bid solicitation).

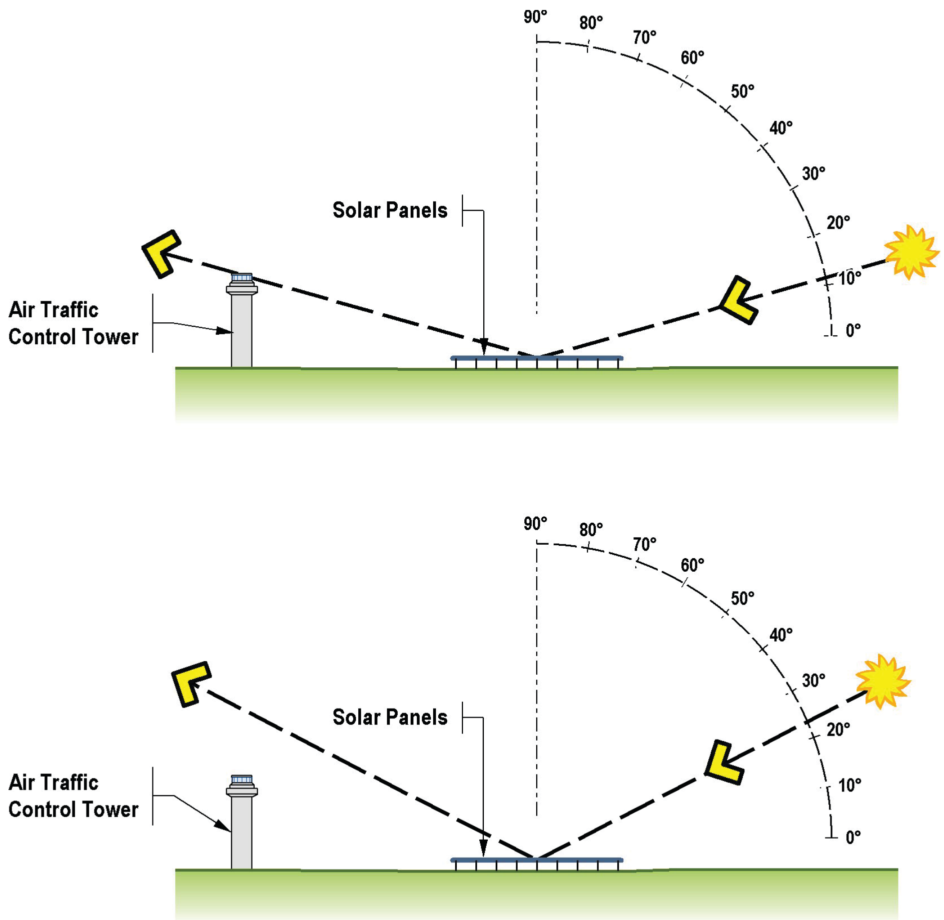


Figure 2-17. Illustration of geometric factors associated with glare on sensitive receptors.

2.6.4.3 Radar Interference and Rotor Wake Turbulence from Wind Turbines

Because radar interference is most often caused by a physical barrier between a radar and a receptor (i.e., plane or airport) sending or receiving a radar signal, most energy technologies can produce an impact if sited too close to a radar installation. However, the greatest problem has been the construction of thousands of 400-foot tall wind turbines that have been located in radar communication corridors. The wind farms create radar shadows behind which the radar signal cannot reach, producing a "blind spot." The rotation of the wind farm blades also creates a signal received by radars that produces clutter, degrading the effectiveness of the radar. These effects are illustrated in Figure 2-18.

While some energy technologies have not been closely evaluated for potential impacts on aviation, this is not the case for wind energy. Due to its capacity to produce a significant amount of renewable energy and achieve public policy mandates for renewable energy, high demand to construct wind projects has forced aviation and military stakeholders to respond to encroachment on the NAS, garnering wind energy installations close scrutiny since at least 2006.

In addition, wind turbines destabilize the air after it passes by the rotors causing turbulence or wake impacts. In wind farms, the turbines are spaced in part to limit impacts to downstream

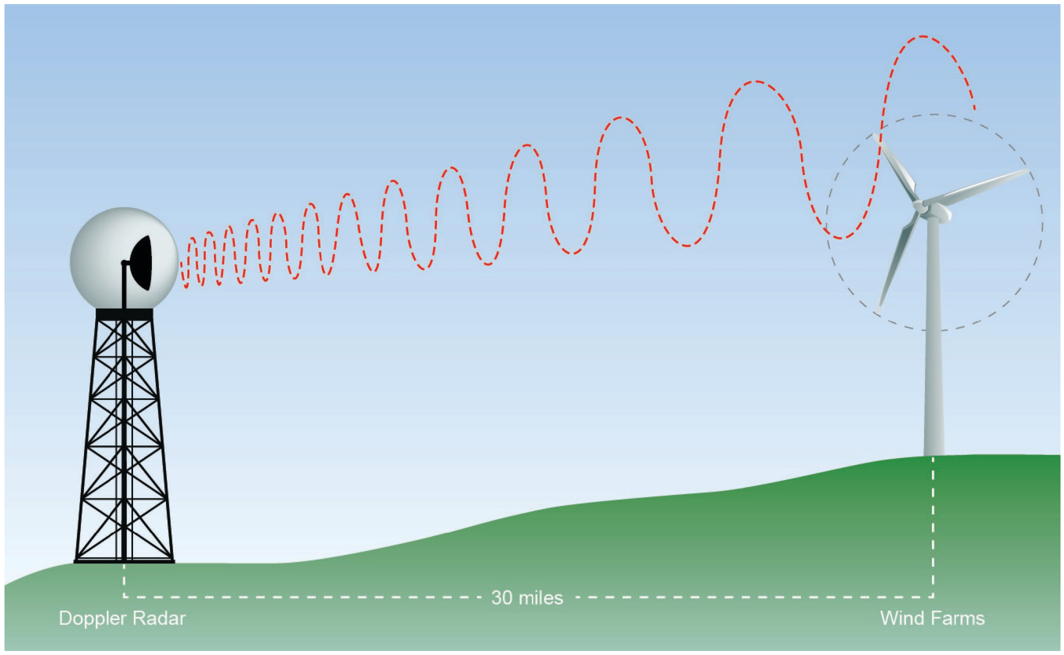


Figure 2-18. Wind turbines as physical obstructions to radar signals.

wind turbines. The destabilized air or turbulence cannot be seen and can produce a safety hazard to particular aircraft including emergency medical helicopters and agricultural applicators. These issues can be of concern downwind of a single row of wind turbines or on the edge of a wind farm.

The lesson of wind energy and aviation has been the need to compromise. Wind energy provides important benefits for national security, economics, and the environment. However, airspace is a finite resource, central to supporting commercial and recreational aviation, emergency response, and military readiness. Project development is subject to a review process facilitated by the FAA and contributed to by the military and other government agencies with a variety of interests. Through that process, individual projects must demonstrate how they are avoiding and minimizing impacts on airspace and, if required, how they will mitigate for unavoidable impacts. The approval may be an opportunity to restrict airspace around the wind farm and protect airspace in areas where the supporting system needs improvement.

After about 10 years of active dialogue on the matter, research and compromise will continue to be necessary. The DOE, FAA, Department of Homeland Security (DHS), and DOD have taken lead roles in this process, focusing on development of radar mitigation technologies that can be deployed throughout the country. Interagency coordination will be important for avoiding and mitigating potential problems early in the process.

2.6.5 Federal Airport Obligations

Renewable energy projects must meet FAA procedures for airport design, planning, construction, and operations as required for federally-obligated airports. Table 2-1 lists and summarizes legislation that obligates airports (*54*). Important considerations associated with proposed projects include conformity with FAA grant assurances, consistency with the ALP, determination of fair market value for any third party property transfer, prohibition against revenue diversion, and consistency with local zoning.

Table 2-1. Legislative programs obligating airports.

Program	Description
Surplus Property Act of 1944 (SPA), as amended, 49 U.S.C. §§ 47151-47153	Surplus property instruments of transfer were issued by the War Assets Administration (WAA) and are now issued by its successor, the General Services Administration (GSA). However, the law gives the FAA (delegated to FAA from the Department of Transportation) the sole responsibility for determining and enforcing compliance with the terms and conditions of all instruments of transfer by which surplus airport property is or has been conveyed to non-federal public agencies pursuant to the SPA. 49 U.S.C. § 47151(b).
Federal-Aid Airport Program (FAAP)	This grant-in-aid program administered by the agency under the authority of the Federal Airport Act of 1946, as amended, assisted public agencies in the development of a nationwide system of public airports. The Federal Airport Act of 1946 was repealed and superseded by the Airport Development Aid Program (ADAP) of 1970.
Airport Development Aid Program (ADAP)	This grant-in-aid program administered by the FAA under the authority of the Airport and Airway Development Act of 1970, as amended, assisted public agencies in the expansion and substantial improvement of the Nation's airport system. The 1970 act was repealed and superseded by the Airport and Airway Improvement Act of 1982 (AAIA).
Airport Improvement Program (AIP)	This grant-in-aid program administered by the FAA under the authority of the Airport and Airway Improvement Act of 1982, 49 U.S.C. § 47101, et seq., assists in maintaining a safe and efficient nationwide system of public-use airports that meet the present and future needs of civil aeronautics.

2.6.5.1 Grant Assurances

A federal grant assurance is a provision within a federal grant agreement to which the recipient of federal airport development assistance has agreed to comply in consideration of the assistance provided. Any renewable energy project which receives FAA funding under the AIP must comply with the terms of the grant. These requirements are broad and provide FAA with direct oversight with all aspects of the project. The list of grant assurances for airport sponsors was updated in April 2014 (*55*).

2.6.5.2 Airport Layout Plan

Airports engage in long-term facility planning by developing airport master plans and an ALP. An airport master plan is a comprehensive study of an airport that describes the short-, medium-, and long-term development plans to meet future aviation demand. In accordance with AC 150/5070-6B, master plans are developed through a collaborative process to engage the airport, agencies, businesses, and stakeholders in planning for the airport's future. The purpose of the master plan is to identify critical issues related to the airport's infrastructure and direct financial resources to address those issues. The ALP is then modified to include future infrastructure improvement projects identified in the master plan.

Airports are beginning to recognize the potential for renewable energy and may wish to identify possible future project locations in the master plan and potentially the ALP. Referring to the ALP is critical for both aviation compatibility and good renewable energy project planning. Airport sponsors should review the ALP to determine if future projects are planned that might interfere with sites appropriate for renewable energy. As specified in AC 150/5070-6B, an ALP depicts both existing and planned land uses and facilities at an airport.

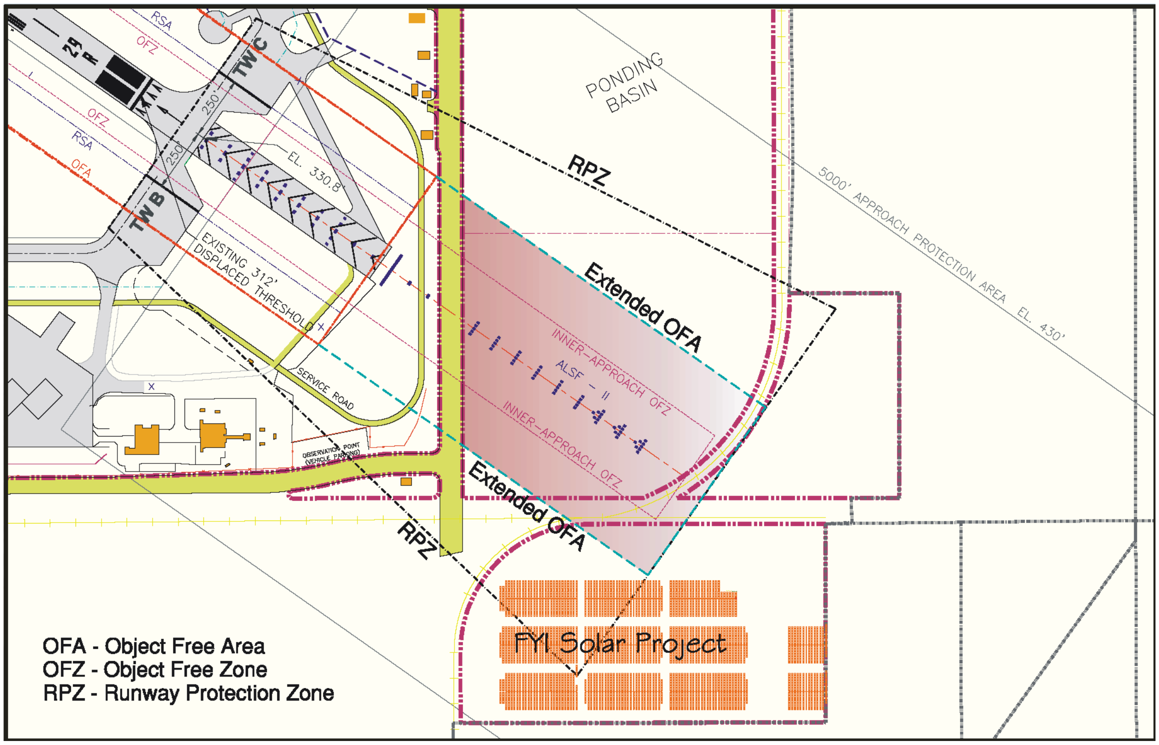
Grant Assurance No. 29 requires that an airport's ALP depict the location of all existing and proposed non-aviation areas and of all existing improvements thereon, and each amendment, revision or modification of the ALP is subject to the approval of the FAA. The built environment typically shown on the ALP includes the outline of a building footprint or the limits of pavement.

Converting Land to a Non-Aeronautical Use: Airports that seek to use land designated on the ALP as aeronautical purpose for revenue producing, non-aeronautical uses such as a solar farm must request a waiver of aeronautical land use assurance from the FAA. The request must demonstrate that the land is not needed for current or future aeronautical use, will not impact airport operations, and that proceeds from the conversion are in accordance with FAA policy associated with revenue diversion. The FAA provides public notice of the waiver request in the *Federal Register* and accepts comments during a 30 day public comment period. Barnstable and Indianapolis are two airports that obtained waivers from the FAA to accommodate solar facilities leased to third party developers. See Case Summaries 5.1 and 5.10.

Facilities collocated with existing structures, such as an elevator shaft on the roof of a terminal building, are usually not depicted on the ALP as they are located within the footprint of the collocated structure. Without changing the footprint outline of the structure, the collocated facility does not constitute a change to the ALP and subsequently a federal action. While the need for plan updates will vary depending on the number and type of projects completed by airports, the airport is required to update the ALP if one has not been completed in several years. Grant assurances state that the sponsor must maintain an up-to-date ALP. In general, solar installations at airports are either collocated with existing facilities or installed independently on the ground.

Concurrent use: A request from the airport sponsor to designate airport property as a "concurrent use" can be submitted prior to submitting a land release request. A concurrent use is the use of dedicated airport property for a compatible non-aviation activity while at the same time the property serves the primary purpose for which it was acquired. Examples of a concurrent use are road right-of-way easements, utility easements, and agricultural uses (FAA Order 5190.6B for more information). Chicago-Rockford Airport obtained a concurrent use determination for its project. See Case Summary 5.6.

ALPs show various safety and planning zones established by the FAA and regulating placement of facilities. Zones are established based on distance to the runway or taxiway centerline or proximity to the runway end. Some zones closest to the runway are restricted to frangible structures required for airport operations (i.e., the object free area or OFA). Other areas restrict the height of structures with very low profile items potentially occurring closer to runways and taller structures limited to greater distance based on a defined distance to height ratio. The runway protection zone or RPZ is a trapezoid-shaped area at the end of the runway established to restrict land uses for the protection of people and property. Given recent interest of airports in locating solar facilities in the RPZ to obtain some financial benefit from a portion of the airport property that is restricted from most other uses, the FAA issued Interim Guidance on Land Uses in the Runway Protection Zone in September 2012 (*56*). It requires airport sponsors to provide the FAA with an alternatives analysis for solar projects (and other specified uses) proposed in the RPZ to demonstrate why the facility cannot be located elsewhere on airport property. Unlike most other FAA approvals that are reviewed by the regional office, the RPZ alternatives analysis must also be submitted to and receive approval from FAA headquarters. Figure 2-19 shows the



Source: Fresno-Yosemite International Airport

Figure 2-19. Location of solar project at Fresno-Yosemite Airport relative to RPZ.

location of a 2 MW solar facility at Fresno-Yosemite International Airport (FYI) constructed in 2008 and located partially inside the RPZ but outside the OFA.

2.6.5.3 Fair Market Value

Land releases where land is leased to a private entity for a 15–25 year period to own and operate the facility are often necessary for renewable energy projects. In order for the sponsor to lease land for a non-aeronautical purpose (such as electricity generation), it must receive a formal approval from the FAA to ensure that the lease is in compliance with its obligation under FAA grant assurances.

Referencing Grant Assurance No. 24, which requires a federally obligated airport to charge fees and rents that will make it as self-sustaining as possible, the FAA requires airports that have received AIP grants to charge "fair market value" for the lease of airport land and facilities for non-aeronautical uses. Thus, if a power company seeks to lease an unused tract of land at an airport on which the power company will locate a renewable energy project, unless the energy will be used by the airport itself, the power company must pay the airport fair market rent for such land. Such leases can be an important source of non-aeronautical revenue for airports that have large amounts of unused land, but airports must ensure that such facilities do not adversely affect the aeronautical uses surrounding them or foreclose future aeronautical development. (Note that renewable energy facilities typically have a useful life of 20–30 years, so that aeronautical development projected to be undertaken beyond such a period of time would not necessarily be inconsistent with development of a renewable energy project on the same portion of an airport.) In contrast, an airport that leases land or portions of a facility to be developed for a renewable energy project where the output will be used by the airport itself may be able to charge only a reasonable amount of rent (which may be none; see Grant Assurance No. 22 "Economic Nondiscrimination"), thereby lowering the overall cost of the project and, therefore, of the energy to be provided to the airport operator. Rents paid by a developer of a renewable energy facility at an airport will constitute airport revenue, which must be used only for airport purposes consistent with federal law (See 49 U.S.C. §§47107, 47133 and Grant Assurance No. 25, "Airport Revenues").

Determination of fair market value can be a difficult undertaking, and is subject to many factors. Several of the Los Angeles Airport (LAX) rate cases have examined the question of determining fair market value in the context of an airport and, although there has not been a clear resolution of these issues, it appears clear that use of "highest and best use" valuation to determine the fair market value of airport land is not acceptable for rate-setting purposes. It is reasonable for any such valuation to take into account the restrictions on use inherent in airport property.

Importance of Obtaining FMV: In 2011, the FAA ruled that a solar installation at Glendale Municipal Airport was in violation of Grant Assurance 22 which grants FAA approval of aeronautical lands for non-aeronautical uses and requires fair market payment for use of that land. In 1999, the airport leased a 1.5 acre parcel of land to Arizona Public Service (the local utility) for $10 a year. The system, built in two phases, is rated at 172 kW of power. The FAA has notified the airport that it is in jeopardy of forfeiting federal grants averaging $150,000 per year unless the action is corrected.

In order to insulate an airport from claims that it is impermissibly diverting airport revenue by charging a below-market rental rate, airports will often obtain an appraisal from a licensed third party appraiser of the fair market rental of the land to be leased. Such an appraisal will take into account the rents charged to other non-aeronautical tenants at the airport, if any, as well as rents charged for similar uses in areas neighboring the airport. Another means of determining fair market value may be to discount the value of the land to a developer of an alternative energy project over the term of the lease by first estimating the annual revenue to be generated by the project, then allocating a portion of the expected revenue to be generated by the project to the costs of developing and operating the facility, assuming a reasonable return (profit) for the developer, and allocating the remaining revenues to the land rental. Where an airport seeks to license or lease only a portion of a site, for example the right to locate solar panels on rooftops or the air rights above surface parking, the method of determining fair market value is even more difficult, especially where there are few if any comparable projects in the surrounding area. In such cases, an economic value method may be the only reasonable means to determine fair market rental value.

In cases where a land lease is necessary, the sponsor must submit documentation that describes, among other items, the airport's obligations to the land based on how it was acquired, the type of land release request, justification for the release, demonstration that the airport will obtain fair market value in return for the release, and what will be done with the revenue that is generated by the release. The proposed action subsequent to the release must be shown to be in compliance with the ALP. In most cases, the FAA prefers that airport land not needed for aeronautical use be leased rather than sold so that it provides continuous income for airport purposes and preserves the property for future aviation usage so long as the future use is compatible with airport operations. Land acquired with AIP noise compatibility grant funds must, generally, be sold after the airport sponsor converts the land to compatible uses. The sponsor must submit to the ADO the request to change the ALP and update Exhibit A to show that the property will be used for non-aeronautical purposes. As stated previously, the FAA's approval either to release property for use as a renewable energy facility or to concur with an appropriate lease of suitable airport property may constitute a federal action triggering a NEPA review that must be completed prior to FAA issuing a land release.

Land lease values for representative airport solar projects are provided in Table 2-2.

Table 2-2. Published fair market value and land lease rates for solar projects.

Airport	Year	Area (acres)	Annual Lease Rate	Source
Chicago-Rockford	2011	69 acres	$160 / acre	FAA Letter dated 5/2/2011
Denver II	2009	9.366 acres	$352.34 / acre	Denver City Council Approval, 8/19/2009
Denver IV	2013	12 acres	$340.21 / acre	Denver City Council Approval, 4/4/2013
Indianapolis (Phase II)	2014	76.592 acres	$871.20 / acre	FR - 9/16/2014
Indianapolis (Phase III)	2015	22.1 acres	$5,342.98 / acre	FR – 2/19/2015
Warren Field (NC)	2014	35.9 acres	$1,200 / acre	Press report

2.6.5.4 Revenue Diversion

The AAIA established the general requirement for use of airport revenue that directed public airport owners and operators to use all revenues generated by the airport for the capital or operating costs of the airport, the local airport system, or other local facilities which are owned or operated by the owner or operator of the airport and directly related to the actual transportation of passengers or property [Codified at 49 United States Code (U.S.C.) § 47107(b)]. Airports must demonstrate that any revenue generated on airport by renewable energy projects is used for airport purposes.

2.6.6 Electrical Interconnection

Developers of renewable energy projects need to interconnect their project to the electric grid. These arrangements will differ depending on what type of renewable energy project it is. Utility-scale projects, i.e., large scale output projects, will typically enter into a large generator interconnection agreement with the applicable utility or system operator. To do this they will have to go through a series of studies (feasibility studies, system impact studies, and facility studies) to assess the impact of the project on the existing grid arrangements. These studies may indicate that upgrades are required to the existing transmission system to facilitate the renewable energy project coming on-line.

Distributed generation renewable energy projects (i.e., projects that supply power directly to the customer such as a solar system on the roof of a terminal or parking garage) will not be required to go through such complex studies but will need to adhere to the “net metering” requirements of the applicable electric utility so that any power produced by the renewable energy project that is not used by the immediate customer can be sold back into the grid. Interconnection requirements typically also seek to ensure that the renewable energy facility’s equipment is compatible with industry standards and provides appropriate safety standards, including allowing the renewable energy project to be disconnected from the grid when downstream maintenance is required.

2.7 Operational and Safety Considerations

There are a number of logistical issues that should be considered when planning for the operations of a renewable energy project on airport property. Many of these are associated with the need to control access to secure areas of the airfield where projects may be located. There is training of both airport staff and contractors to ensure that appropriate access and security procedures are followed. There are also particular renewable energy technology-related factors that airports need to consider and plan for during the operational phase.

2.7.1 Staff Training

Airport staff will require some renewable energy related training to provide education on the operation of the technology and procedures for interacting with product support. In cases where the airport does not own the facility, some introductory training from the project developers about the facility and its operations will benefit the airport staff during the regular daily assignments. For example, it will be important to know how often project staff might be expected to visit the project site and what types of activities they may be undertaking so that there are not concerns about trespassing on airport property. In cases where the airport does own the facility, they will need to be much more informed about operations and maintenance and communication with the contractors and vendors and trusted advisors as they get up to speed on the operational logistics. All staff should receive some general education about the project and be referred to a project website so that they can share information on the project with industry colleagues and the public.

2.7.2 Technical Support

Given the lack of familiarity with renewable energy technologies, airport renewable energy projects will require outside expertise to help operate and maintain the facility. Where the airport owns the project, product support and contractors will work with airport facility staff to monitor operations, perform routine maintenance, and identify more substantial issues. Technology providers will provide support based on the terms and conditions of any warranty. Airport personnel will need clear information on who to contact and when for accessing technical support under a valid warranty. Other parties may also be active early in the operational phases including the Engineering Procurement and Construction (EPC) contractor to troubleshoot start-up issues and optimize system performance. In cases where a third party owns the facility, the airport will primarily need to know operations and maintenance activities as it relates to access to airport property and any other communication related terms of the land lease.

2.7.3 Security

Airport security, as the travelling public knows, has intensified since 2001. Beyond the standard procedures that travelers go through to board commercial aircraft, there are a myriad of training and access procedures required for airport personnel and contractors to access specific areas of the airport including locations where renewable energy facilities might be located. Airports need to plan for transit by project partners from the public street to secured areas both during installation and for long-term operations and maintenance procedures. This includes early communication with project partners about the level of training necessary to acquire badged access and regular procedures necessary to gain access without incident. Security may also affect the time of day that the project site can be accessed so limitations on access need to be communicated early and incorporated into the access plan.

2.7.4 Warranties

Technology and performance warranties have been an important part of renewable energy development as they provide assurances that renewable energy professionals and technology providers will remain engaged in the project in the early stages to ensure that the technology performs as promised. Technology providers will offer standard warranties on renewable energy products backed by a standard level of technical support. Owners can purchase extended warranties to provide additional levels of surety. Warranties can be structured in different ways. As an example, solar panel manufacturers will provide both a term of performance such as 25 years coupled with an annual level of performance for each year of operation typically expressed as a degradation rate (industry standard is 0.5% loss of efficiency annually).

2.8 Evaluation Factors Matrix

An evaluation factors matrix has been developed to facilitate consideration of the various elements of decision-making described earlier. The description of the evaluation factors is included as Table 2-3 and the Evaluation Factors Matrix is included in Table 2-4.

Table 2-3. Description of evaluation factors for renewable energy projects.

Factor	Description
Compatibility/Aviation Safety	The degree to which the technology is compatible with aeronautical activities. Some technologies are generally more compatible than others. Compatibility may be achieved through site specific design and analysis.
Environmental Impact	The degree to which the technology may result in environmental impacts either during construction or operations. While environmental impacts may be avoided or minimized, the potential for impact translates into lengthy permitting.
Ease of Operation and Maintenance	Different technologies have different requirements for routine operations and maintenance (O&M). The relative ease of O&M depends on the ease of access to the site, extent and frequency of activity, and type of equipment needed.
Natural Energy Potential	Technology selection is closely aligned with the availability of natural energy. For some technologies, the lack of available renewable energy will be a fatal flaw. For others, it will be a primary factor in technology selection.
Ease of Interconnection	The renewable energy project will need to physically connect to the existing electrical system. Where the proximity to sufficiently sized components is close and available, costs to interconnect can be reasonable and limited.
Installed Cost of Electricity	All other factors being even, some renewable energy technologies produce electricity more efficiently and cost-effectively than others. Site specific conditions, such as distance to interconnect, would be identified in the future.
Public Policy Incentives	Public policy incentives vary among technologies and political jurisdictions. Incentives from the federal government are available regardless of location. State incentive programs have concentrated markets within particular state lines.
Power Purchase Agreements	Power purchase agreements (PPA) are contracts that parties can enter into to buy and sell electricity and enhance project financing. Some state laws prohibit PPAs which is a fatal flaw for certain types of projects and structures.
Operations & Maintenance Cost	O&M activities vary among technology types. The cost of O&M is one that must be carried through the life of the project and is a fundamental cost consideration even if the work is contracted out.
Potential for Revenue/Savings	Accounting for the factors listed above, the potential for a project to produce revenue or energy cost savings can be assessed. If the project goals are entirely financial, no other factor will influence decision-making on the project.

Table 2-4. Evaluation factors matrix.

	Solar PV	Wind	Geothermal	Biomass	Fuel Cells	Hydro
Compatibility/Aviation Safety	3	2	3	2	3	2
Environmental Impact	3	2	2	2	3	2
Ease of Operation and Maintenance	3	2	3	2	3	1
Natural Energy Potential	3	2	3	2	3	1
Ease of Interconnection	3	2	3	2	3	2
Installed Cost of Electricity	3	2	2	2	1	1
Public Policy Incentives	3	2	2	2	2	2
Power Purchase Agreements	3	3	1	1	2	2
Operations & Maintenance Cost	3	2	2	2	2	1
Potential for Revenue/Savings	3	2	2	2	1	1

* Value applied to each evaluation factor to achieve the renewable energy technology objective
High = 3, Medium = 2, Low = 1

The matrix presents the primary factors necessary to assess the viability of the airport renewable energy opportunity. Ten factors have been identified. There are other factors that should also be considered including modernization of the electrical infrastructure for redundancy and resiliency, and public relations benefits that are not specifically identified. However, as the purpose of the research is revenue generation and cost savings, the factors associated with renewable energy that are not quantifiable have not been included in the matrix. (The project scope identified the following specific evaluation factors: operational considerations, safety considerations, regulatory compliance requirements, environmental issues, capital and maintenance costs, funding sources, incentives, benefit/cost, and return on investment. We considered each of these and have captured them in the 10 factors presented.)

In Table 2-4, a value associated with each factor has been applied to six renewable energy technologies that have been developed at airports or may be in the future. The value is based on a high/medium/low scale with 3 representing high, 2 medium, and 1 low. The matrix provides a screening level assessment to help the reader identify the technologies and factors that are of high value, and those that are of low value, and the specific factors that contribute to that value. [It is important to note that the values are tied to quantifiable financial benefits and may not represent other "green" benefits of pursuing renewable energy.] While the applied values do not consider site-specific issues and thus are a screening exercise, the matrix more broadly informs the reader about the key factors necessary to evaluating airport renewable energy, and provides initial technology selection context.

2.9 Decision-Making Process

This section presents some decision-making tools to help the reader evaluate renewable energy technologies and project types using the evaluation factors described above. Two types of tools are provided: a decision-making checklist and process flow charts.

2.9.1 Decision-Making Checklist

A decision-making checklist has been provided in Table 2-5. It is a focused inventory of the 15 items critical to evaluating a renewable energy project and the corresponding action steps necessary for collecting the required information. The information in the checklist is required regardless of the eventual renewable energy technology selected; however, the interpretation of the information collected will vary based on technology. The information collected by the user who is working through the checklist will be specific to the airport location as energy policies vary among states and utility service territories and the viability of a renewable energy technology will be particular to the project site and potential locations. Unlike the evaluation factor matrix which is a generic screening instrument, the checklist forces the reader to focus on site-specific considerations.

2.9.2 Process Flow Charts

Two process flow charts are provided to aid in project development. The first provides guidance in evaluating appropriate renewable energy technologies. The second provides guidance on exploring project structure and funding.

2.9.2.1 Renewable Energy Technology

A series of process flow charts is provided to facilitate the decision-making process for evaluating the viability of particular renewable energy technologies. There is a flow chart for each technology provided in Figures 2-20 through 2-24. The technologies presented are solar PV, wind, geothermal, biomass, and other (fuel cells, hydrokinetics, and waste-to-energy).

Table 2-5. Decision-making checklist.

	Checklist Item	Action
1	Review renewable energy resource information for your region and determine which resources may be viable	Find Maps available online from the US Department of Energy
2	Review public policy incentives available in your state and locality and determine the value of the incentives	Contact your state energy office or public utility commission
3	Determine if power purchase agreements are allowed in your state	Contact your state energy office or public utility commission
4	Determine the value of net metering credits in your locality	Contact your state energy office or public utility commission
5	Determine the market value of Renewable Energy Certificates	Contact your state energy office or public utility commission
6	Find out if your utility is obligated to purchase renewable energy and, if it is, see when the next bid to purchase renewable energy will occur	Contact your utility or an official with the public utility commission
7	Determine if you are located in an air quality non-attainment or maintenance area and therefore eligible for a VALE Grant from the FAA	Consult your EPA Green Book of non-attainment areas and contact your FAA regional office
8	Determine if you have met eligibility requirements for grant funding under AIP	Contact your FAA regional office
9	Become familiar with your electricity bill and obtain information on the monthly cost of energy over the past 12 months	Obtain information from a facilities or accounting department
10	Review your ALP and determine candidate sites for a renewable energy project based on your preferred technology	Obtain ALP from airport planning department
11	Assess the airspace compatibility of the candidate sites based on your preferred technology	Contact the FAA Obstruction Evaluation Office
12	Determine the viability and relative ease of interconnecting the renewable energy project at candidate sites based on existing utility infrastructure system	Contact the airport facilities department
13	Determine if the proposed project site has any potential environmental issues that could prolong or complicate the permitting process	Contact airport planning office or state office of mapping
14	Obtain an estimate for installed cost of project for initial financial assessment	Contact state energy office or the appropriate industry organization
15	Determine viability of available airport funding from tax exempt bonds	Contact airport financial office

FINAL ACTION: Prepare a project concept and initial financing plan and present it to internal decision-makers

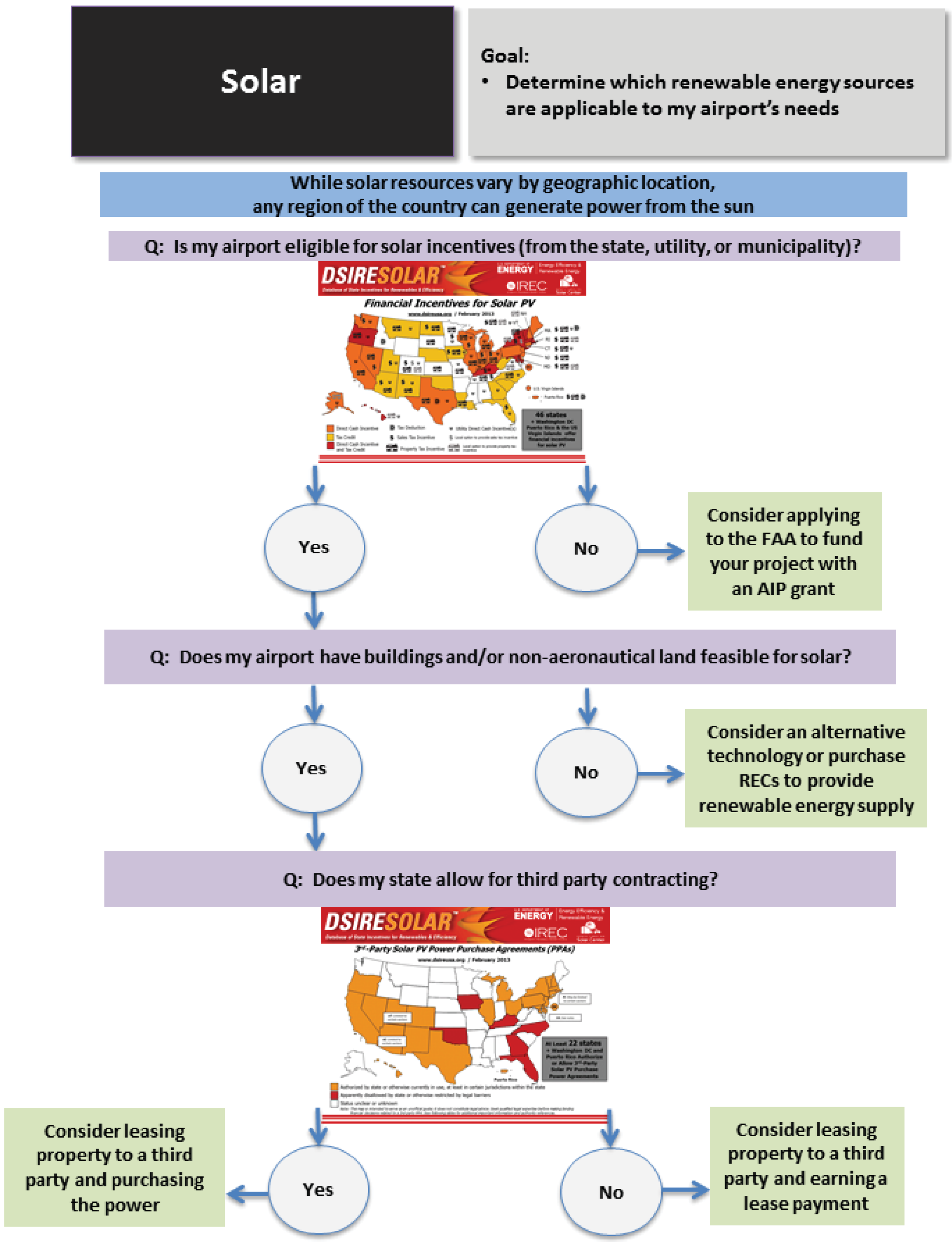


Figure 2-20. Solar PV process flow chart.

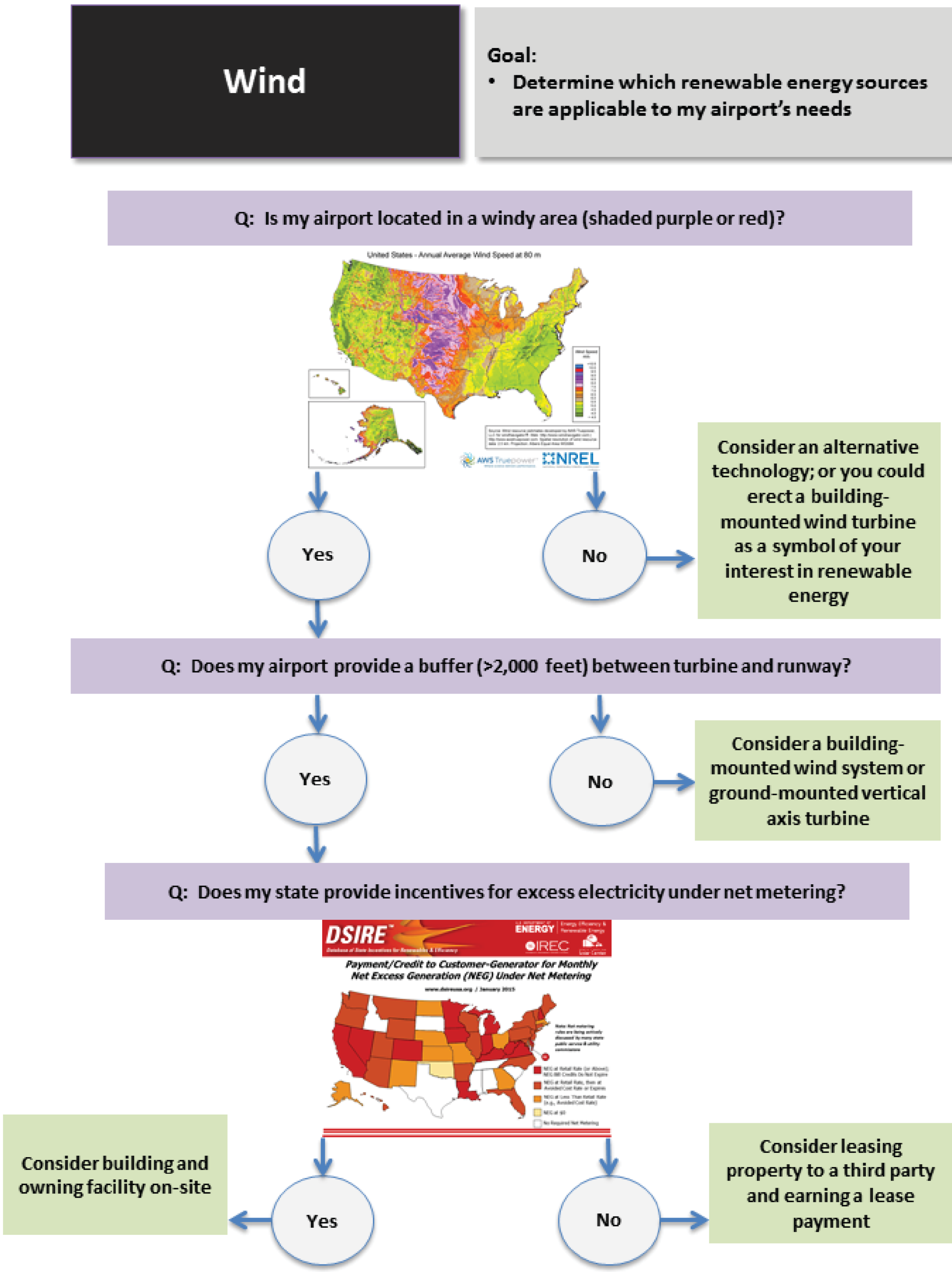
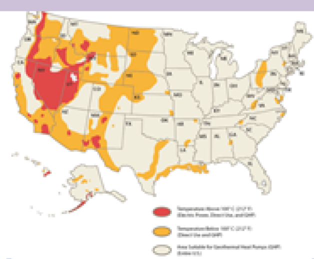


Figure 2-21. Wind process flow chart.

Geothermal

Goal:
- **Determine which renewable energy sources are applicable to my airport's needs**

Q: Is my airport located in a geothermal-rich area?



Yes → Consider a "true" geothermal system that taps heat energy from the earth

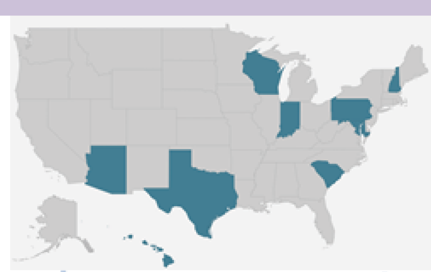
No → Consider a ground source heat pump system as an alternative

Q: Can the Airport co-locate a geothermal system with proposed new construction?

Yes

No → A retrofit installation is typically more costly, but consider assessing its feasibility

Q: Does my state include geothermal as part of the RPS?



Yes → Consider leasing property to a third party and purchasing the power

No → Consider applying to the FAA to fund your project with an AIP grant

Figure 2-22. Geothermal process flow chart.

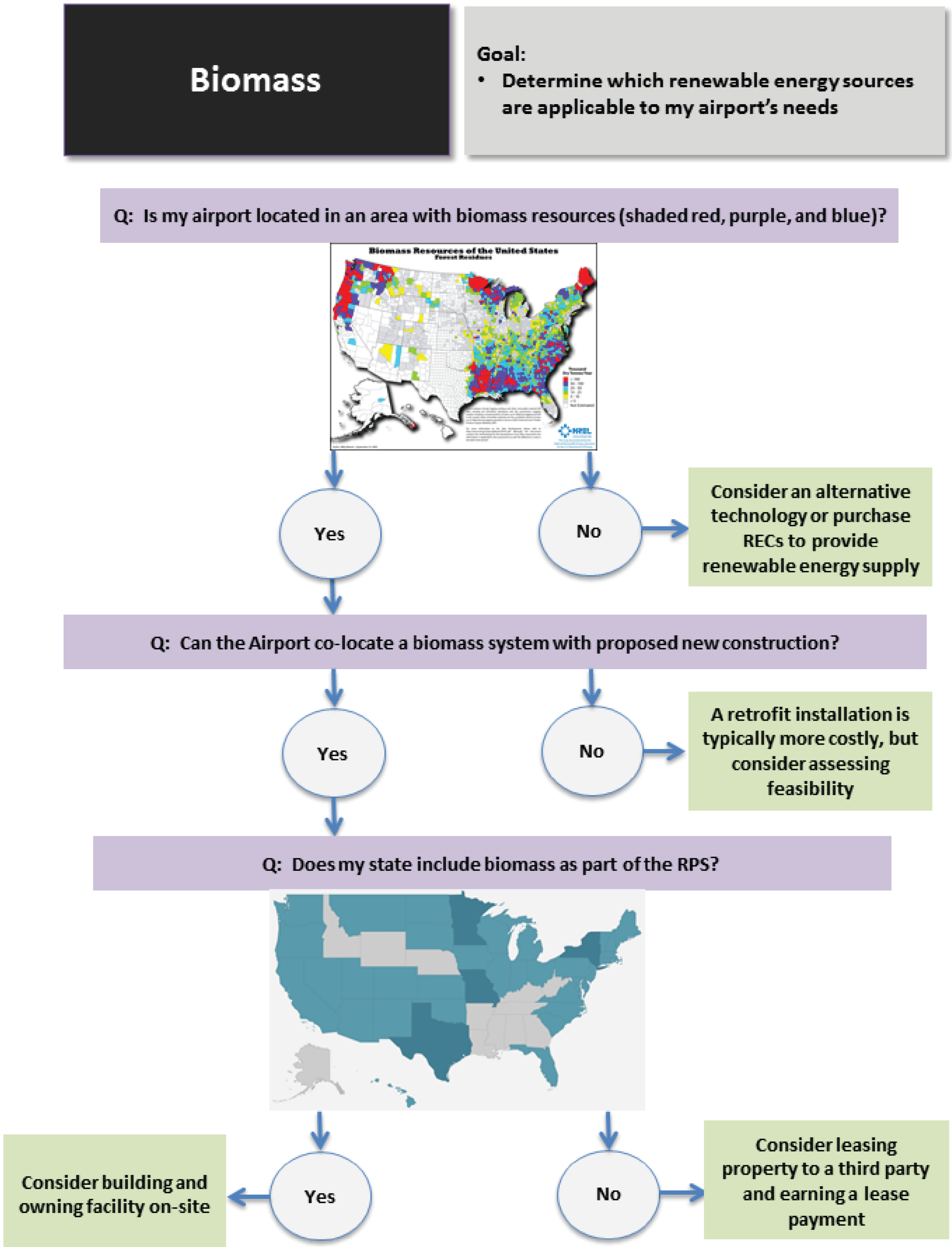


Figure 2-23. Biomass process flow chart.

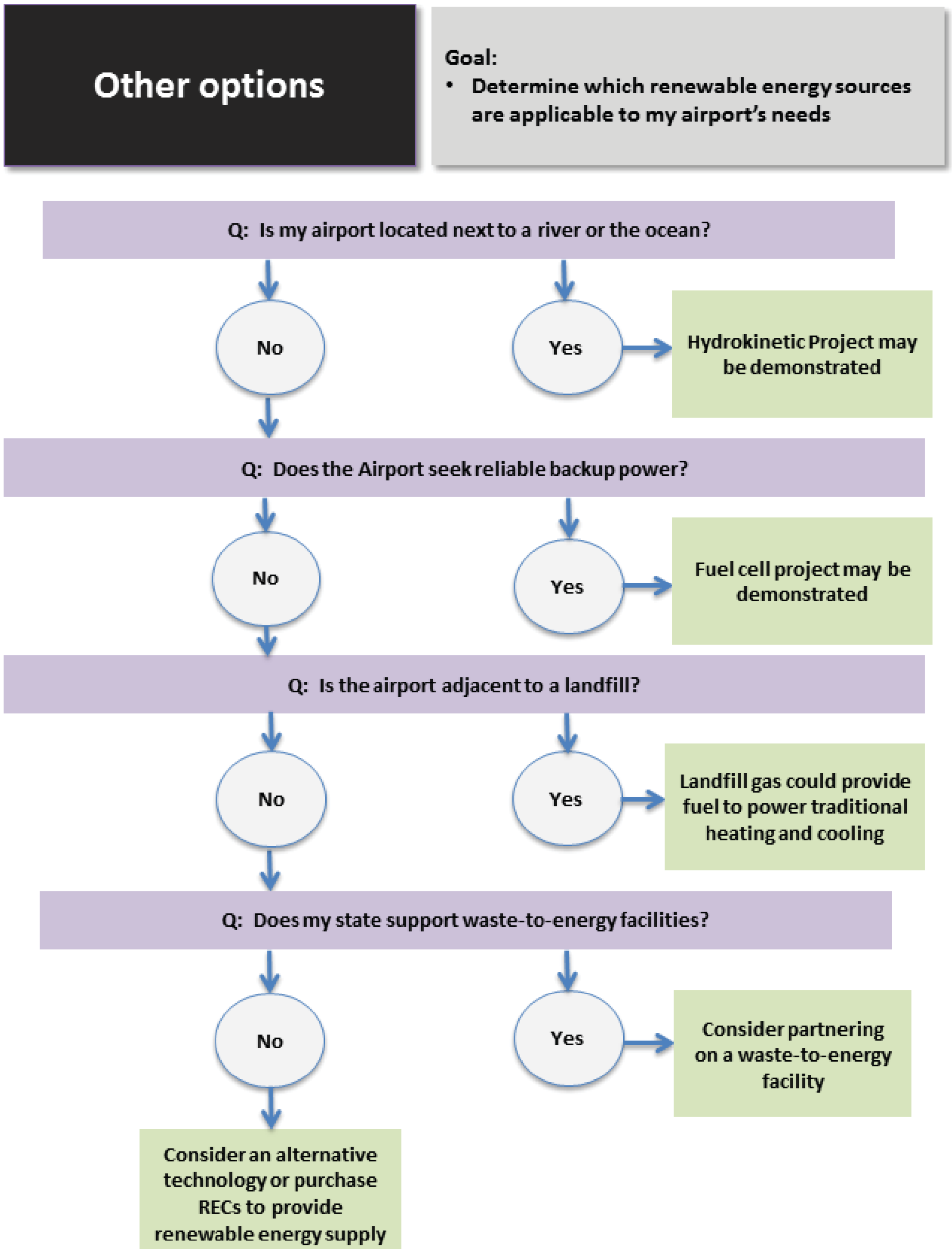


Figure 2-24. Other technologies process flow chart.

Readers can readily move through the flow chart and answer questions to determine if a particular renewable energy technology may be feasible, given a specific project location. Each technology section starts with a map to identify if the project site is located in a geographic area supporting (naturally and politically) a renewable energy resource. The flow chart also provides direction for determining if other project structures and factors may be in place to support a viable project (that is, there may be sufficient renewable energy resource, but the project must be developed in a specific way to be viable). The flow chart focuses on the four technologies that have had the greatest success being developed at airports, while also touching on, in less detail, four additional technologies that are being developed in non-airport environments.

2.9.2.2 Renewable Energy Project

A second series of flow charts (Figures 2-25 through 2-31) is presented to guide the airport's decision-making process based on its individual goals and objectives. Renewable energy can meet a variety of primary objectives from lowering utility costs to advancing emergency preparedness. The reader can select the priorities most important to their situation and proceed through the flow chart to identify a technology and structure that meets their needs.

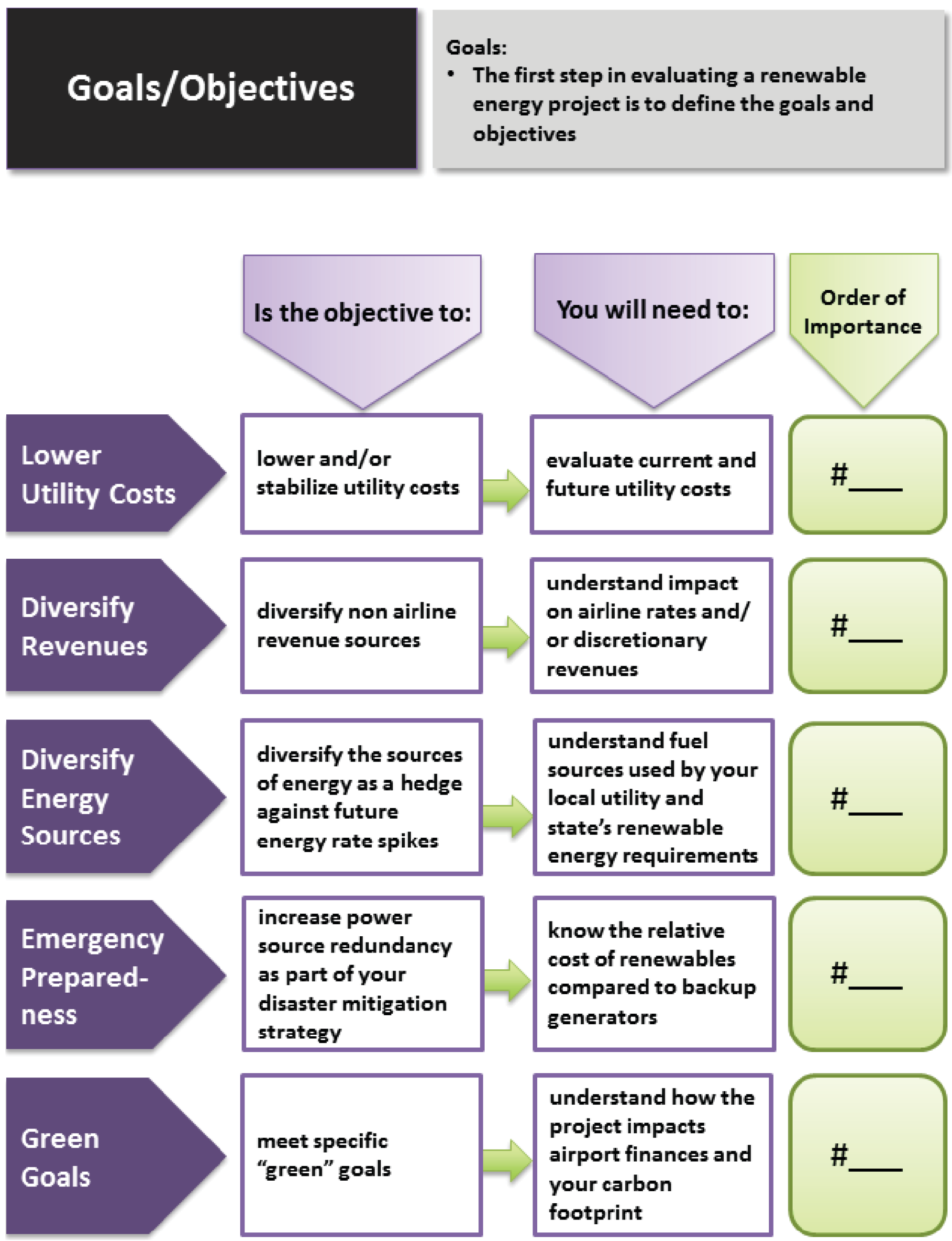


Figure 2-25. Goals and objectives flow chart.

Evaluation Considerations

You will need to:
- Evaluate which deal structure best enables you to meet your primary goals

	GOAL	DEAL STRUCTURE: SITE LEASE	DEAL STRUCTURE: POWER PURCHASE AGREEMENT (PPA)	DEAL STRUCTURE: DIRECT OWNERSHIP
Revenue Enhancement /Cost Reduction Goals	**Lower Utility Costs** [Decision Tree #1]	N/A	Need to compare proposed PPA price to current and estimated future utility costs	Need to calculate per kWh costs of ownership to current and projected future costs
Revenue Enhancement /Cost Reduction Goals	**Diversify Revenues** [Decision Tree #2]	Site lease payments provide additional revenues to airport	N/A [Any site lease payment is usually built into price you are paying for Power under the PPA]	N/A
Revenue Enhancement /Cost Reduction Goals	**Diversify Energy Sources** [Decision Tree #3]	N/A	Need to understand the Utility Company's fuel mix and evaluate how that will impact future charges and compare this to the PPA price	Need to understand the Utility Company's fuel mix and evaluate how that will impact future charges and compare it to the calculated future cost of project ownership
Secondary Goals	**Emergency Prepared-ness** [Decision Tree #4]	N/A	Need to understand the cost of existing emergency generation compared to PPA	Need to understand the cost of existing emergency generation compared to cost of renewable project
Secondary Goals	**Green Goals** [Decision Tree #5]	Optics and public relations of hosting a green project are usually positive however 3rd party ownership of project and RECs may not meet your airport's green goals	Optics and public relations are usually positive	Optics and public relations are usually positive

Figure 2-26. Evaluation considerations flow chart.

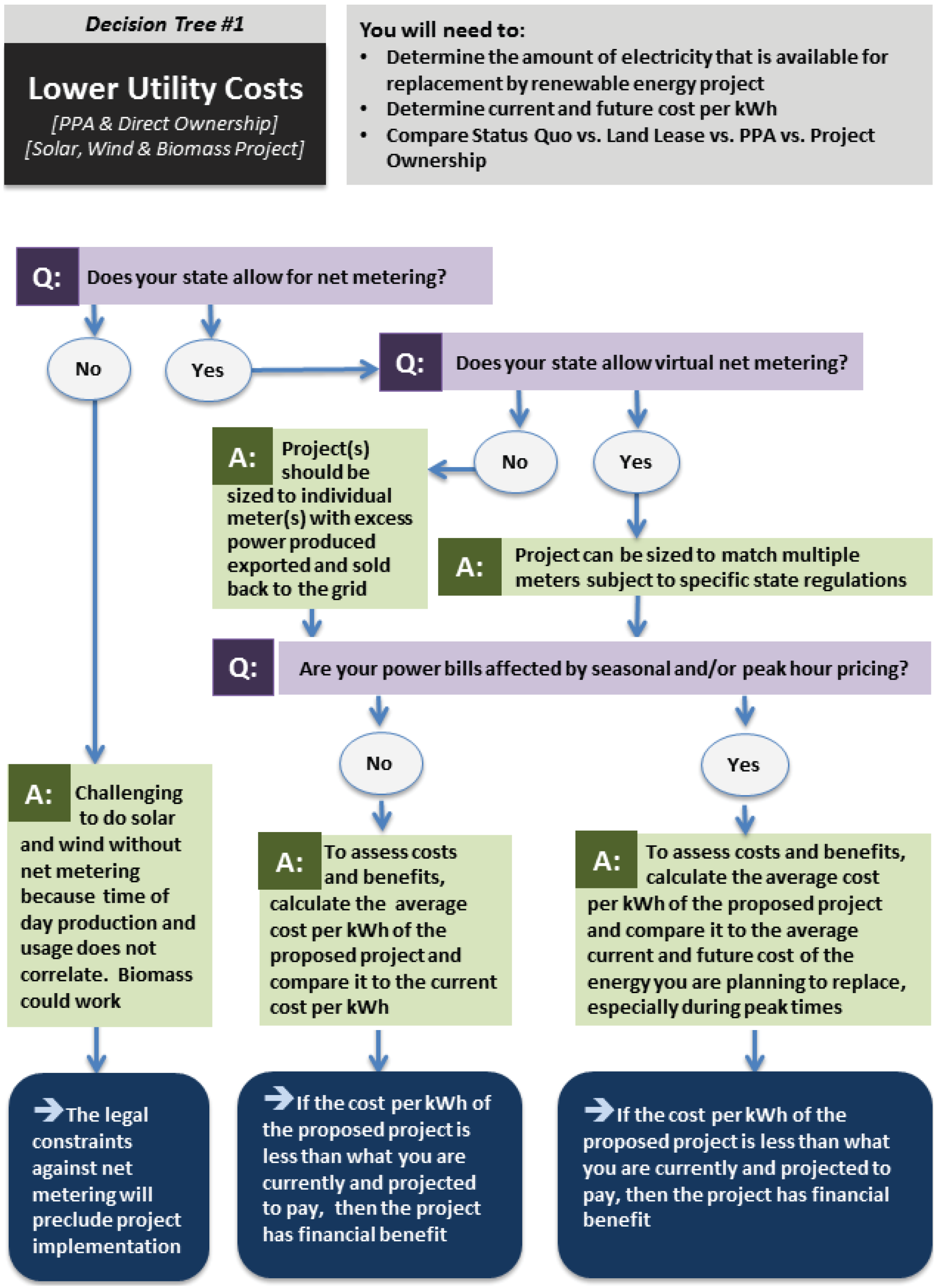


Figure 2-27. Lower utility costs decision tree #1.

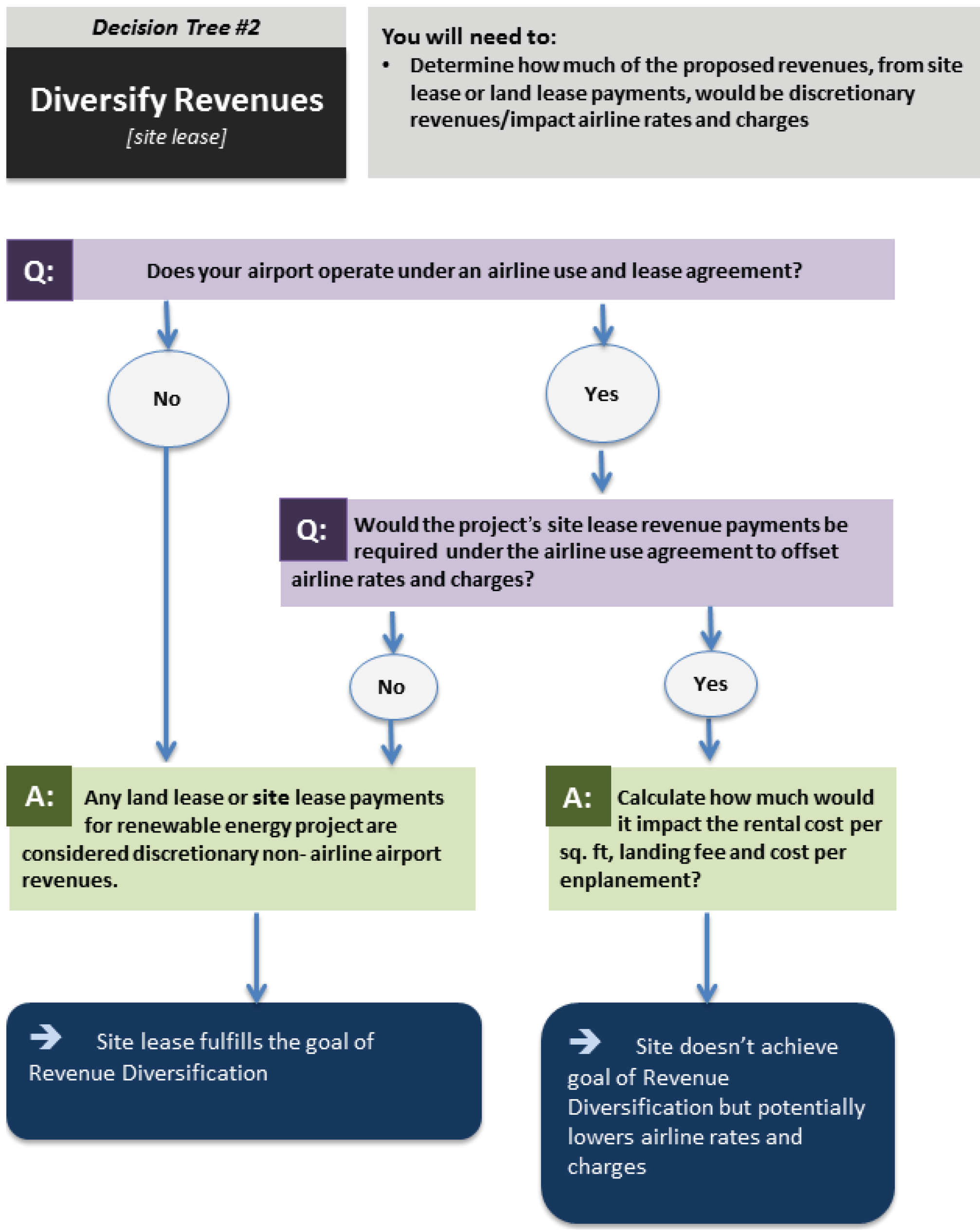


Figure 2-28. Diversify revenues decision tree #2.

Decision Tree #3

Diversify Energy Resources

[PPA, Direct Ownership]

You will need to:

- **Evaluate the importance of mitigating the risk of future increased energy supply costs resulting from the fuel mix of your utility company**

Q: **What is the risk of future price increases based on the type of fuels used by your electric utility company?**

Principal Fuel Source	Low Risk	Medium Risk	High Risk
Nuclear		X	
Oil			X
Natural Gas		X	
Coal			X
Hydro [depends on geographic location]	X	X	
Solar	X		
Wind	X		
Biomass [depends on source of biomass]	X	X	
Solid Waste	X		

A: **Based on the preceding table projected average electricity price increases would be:**

- **Low** 1-3%
- **Medium** 3-5%
- **High** 5-8%

Use these percentages when calculating future energy cost increases

If you have medium or high projected annual electricity cost increase you should consider a renewable energy strategy/project to mitigate future price increase

Figure 2-29. Diversify energy sources decision tree #3.

Decision Tree #4

Emergency Preparedness

[PPA, Direct Ownership]

You will need to:

- **Determine the status of your airport's emergency preparedness planning related to energy and integrate the guidance below as appropriate.**

From the AIP handbook: **a. Redundant Electrical Power Supply Policy.** The interconnection of redundant power supplies may be determined to be necessary by the region at any airport eligible for airfield and/or terminal building lighting where there is a history of cable cuts, extraordinary meteorological conditions, maintenance of remote facilities, or a record of commercial utility interruptions.

For those airports that aren't deemed eligible they must use their own resources or state money to pay for back up generation.

The draft AIP handbook expands this a bit:

Emergency Generator (Acquire, Install or Rehabilitate)

(1) Fixed standby generators necessary to support the following lighting on Cat II/III runways are eligible (not limited to entitlement funding):

A fully functional emergency generator that meets FAA design standards.

(a) Runway touch down zone, centerline, and edge lights.
(b) Land and hold short lights.
(c) Taxiway edge lights for taxiways serving the runway.
(d) Surface movement guidance and control system (SMGCS) lights.

(2) Specific airports have been designated as continuous power airports and are eligible for fixed generators (not limited to entitlement funding). They provide continuous operations in the event of an area wide power failure. The current versions of FAA Order 6030.20, Electrical Power Policy, and FAA Order 6950.2, Electrical Power Policy Implementation at National Airspace System Facilities, list these airports and the designated runways. These orders outline the fixed generator requirements.

(3) Per FAA policy, for airports that do not meet one of the two criteria listed above, one fixed generator is eligible to support AIP eligible airside infrastructure. Only entitlement funds can be used in this case.

(4) Per FAA policy, fixed emergency generators are only eligible for terminal use for the specific purpose of meeting life safety code requirements for building evacuation.

(5) The generator must be a fixed generator, not a mobile generator.

As a goal using renewables for backup generation would probably not be the primary goal but a secondary add on.

To evaluate it:
How much backup energy resources are currently in place?
How much is needed/required/desired?
What are the primary sources: Diesel, gas, renewable energy?

Figure 2-30. Emergency preparedness decision tree #4.

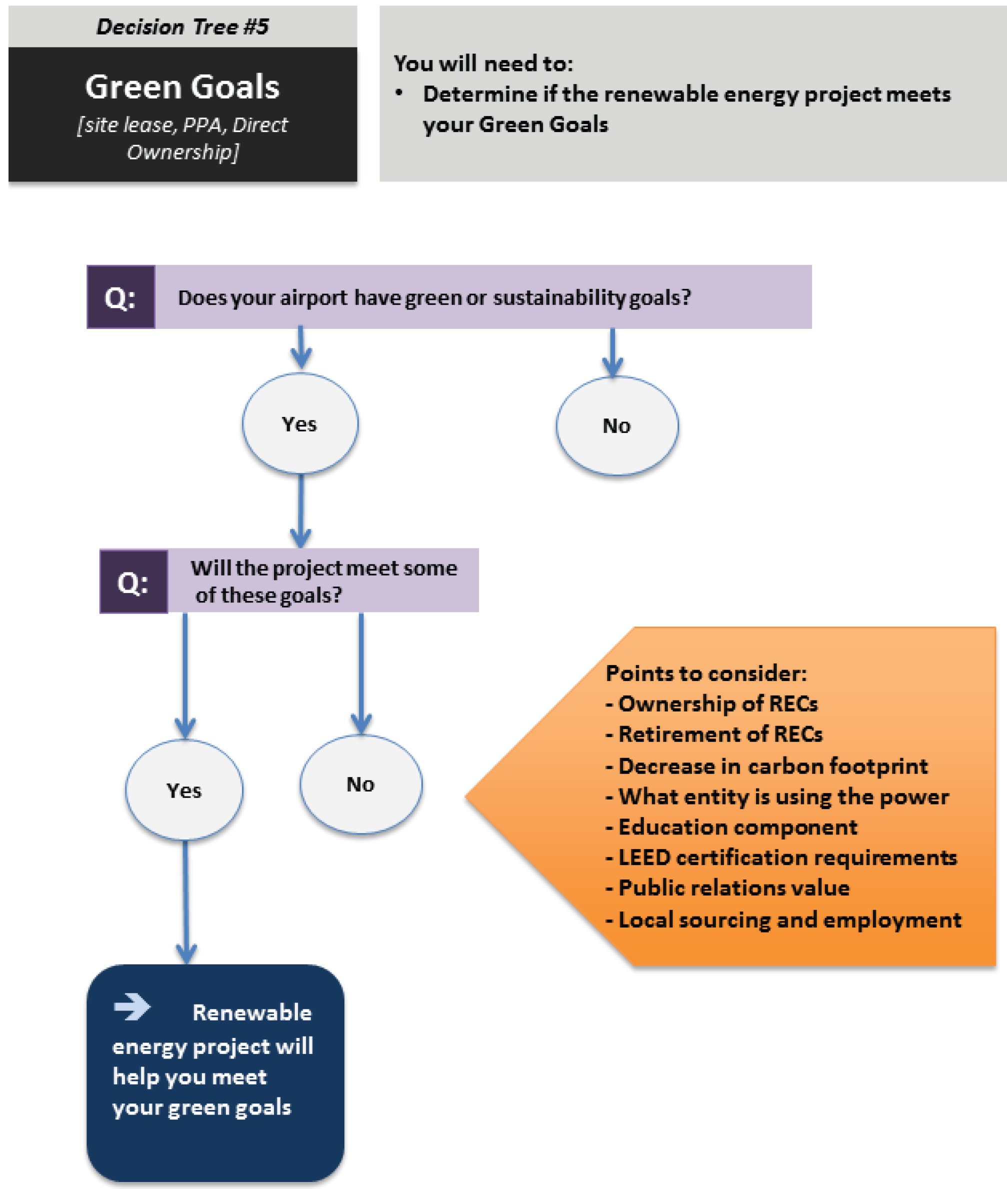


Figure 2-31. Green goals decision tree #5.

CHAPTER 3

Conducting Financial Assessments of Airport Renewable Energy

Airports not only need to facilitate safe air travel, but also need to do so in an efficient and profitable way. The forces on airports to do so come both from federal legislation and market-based drivers.

Under federal aviation law referred to as grant assurances, the aspirational goal is that federally-obligated airports are self-sustaining and do not require subsidies from general purpose funds. Local governments that operate airports have a strong incentive to help make the airport self-sufficient as any general tax revenues or assets it directs to the airport that are not specifically characterized to be loans cannot be recovered due to federal prohibition on revenue diversion. Furthermore, local government has many other demands on its services and isolating airport operations as a separate entity relieves one source of financial pressure on government budgets (*57*).

Airports also compete with each other for business. They do so by negotiating agreements with airlines and concessionaires, managing business commodities like parking and fuel costs, and developing alternative revenue sources. Managing an airport during a time of dynamic changes to the commercial airline business requires airport managers to consider creative ways to establish stable, long-term revenue and cost saving structures.

This chapter reviews the financial factors that should be considered in evaluating renewable energy projects. It includes reference to modeling tools in Section 3.6 that airports can use to help them evaluate specific project types given the location of their airport. In particular, the reader is directed to a financial analysis tool in Section 3.6.3 developed under *ACRP Report 110: Evaluating Impacts of Sustainability Practices on Airport Operations and Maintenance*, which can be used to prepare a site-specific financial analysis for a renewable energy project.

3.1 Types of Financial Benefit

Renewable energy projects can provide opportunities for airports to generate new revenue and achieve long-term energy cost savings.

3.1.1 Revenue Generation

More and more, airports are looking for creative ways to utilize their assets to generate alternative revenue sources. When it comes to renewable energy, the majority of financial benefits are accrued through cost savings rather than revenue generation which are described in Section 3.1.2. Cost savings are more applicable to airports because they consume lots of energy and investments in renewable projects typically result in an off-set to those energy operating costs. The primary method for airports to raise revenue through renewable energy projects is by entering into a property lease with a private renewable energy developer. A second possibility is a surcharge on a tenant owned system.

3.1.1.1 Property Lease

A land lease for a renewable energy facility on airport property is not particularly different from any other land lease agreement. The airport must assess the fair market value (FMV) of the land and demonstrate to the FAA that it is receiving FMV compensation through the lease. Renewable energy developers will seek to keep their costs down to ensure that the electricity produced can achieve a market rate. As a result, lease values for renewable energy projects are more comparable to those obtained for agricultural leases and often significantly lower than for other types of development such as commercial or industrial tenants. The best locations for siting projects on airfield lands are those sites with few other development alternatives such as noise compromised lands or areas with height restrictions due to close proximity to the airfield.

It is important to note that airports that lease land for a renewable energy project and receive only a lease payment in return do not have a credible claim that it is using renewable energy to power the airport. The party that executes a PPA to buy the energy has a valid claim to the green power produced and owns the REC to document that claim. However, the public at-large is likely not able to recognize this distinction and the airport will benefit indirectly from the perception that it is using renewable energy.

3.1.1.2 Tenant Surcharge

Tenants may lease airport buildings or construct and own a building through a long-term lease arrangement. In either case, the tenant is often responsible for paying its own utility bills and the airport is not involved in these transactions. In cases where the tenant wishes to install a renewable energy project on a building it owns or adjacent to a building it occupies, it seeks to do so to gain a long-term financial benefit from the renewable energy. It may be possible for the airport to assess a fee for allowing the deployment of the renewable energy system without discouraging the tenant from proceeding with the project, though the amount of money is likely relatively small.

3.1.2 Cost Savings

There are a number of ways that an airport can obtain cost savings from its regular energy bill through the implementation of a renewable energy project.

3.1.2.1 On-site Generation

When an airport builds and operates its own renewable energy system, the power it generates supplants electricity (or fuel for heating) previously purchased from the utility. The value of the energy no longer purchased from the utility represents a cost savings to the airport. The savings accumulate over time to a point where the value of the savings equals the cost of installing the system. This is customarily known as the simple payback period. Once the system is paid off, the energy that is produced on-site is nearly free with the exception of any operations and maintenance expenses which tend to be small for renewable technologies.

3.1.2.2 Sale of Net-Metered Electricity

As described in Section 2.4.6, net metering refers to the utility's purchase of surplus electricity generated by the renewable energy system. The purchase may come in the form of a credit on the utility bill or a check in the mail. Because the generator made an investment to build the renewable energy system, the value of the electricity sale can be considered a cost savings that is used to calculate the payback period. While the value of the sale on a kilowatt-hour basis will vary depending on the particular state and its net metering policy, the utility is obligated to purchase the surplus electricity. Therefore, the net metered power will produce a cost savings to the generator.

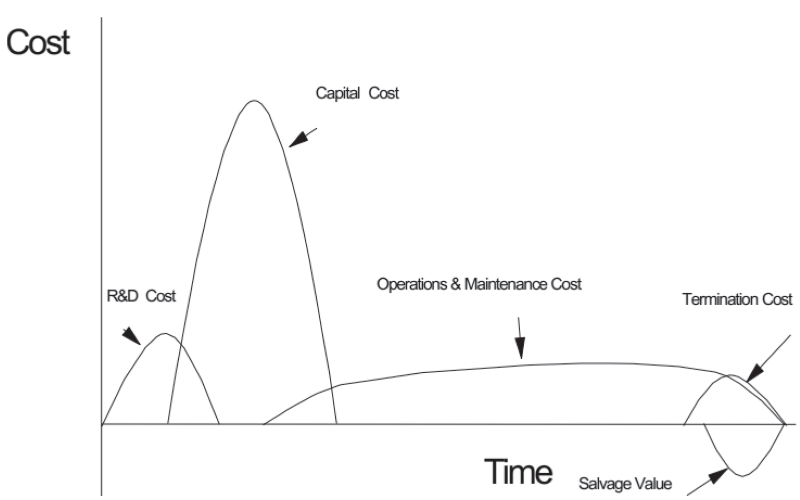
3.1.2.3 Sale of RECs

As described in Section 2.4.3 above, owners of renewable energy facilities generate both energy and RECs. The value of the electricity (or heating fuel) is determined by the spot market price or a pre-set price in a bulk purchase contract. The value of the REC is also set by market demand by REC buyers who include utilities that are obligated by law under an RPS to procure renewable energy by purchasing RECs and institutions whose constituents strongly desire that green power be purchased from a voluntary market (e.g., corporations, universities, health care). The sale of the RECs, like the sale of surplus electricity, can be used to pay off the investment that was necessary to build the renewable energy facility and therefore represents a cost savings. However, current FAA guidance states that RECs created by projects funded with AIP funds associated with Section 512 of the FAA Modernization and Reform Act of 2012 cannot be sold to generate revenue (*58*). The airport can give the RECs to the utility in return for lower electricity rates. RECs accrue for both on-site generation and net-metered electricity. As noted previously, the sale of RECs transfers credit for the renewable energy to a third party who seeks to document and verify its purchase and, therefore, the seller of the REC releases the claim to renewable energy to the purchaser.

3.2 Capital and Maintenance Costs

Capital and maintenance costs must be incorporated into the financial assessment of any renewable energy project regardless of the owner. For an airport owned and financed project, the predicted project cost will be compared to annual cost savings to calculate a simple payback period. For a third party owned project, the project costs will be financed by debt and equity. The annual revenue stream produced through the power purchase agreement must be sufficient to pay off the debt service and provide investors with capital repayment plus their required rate of return (e.g., 10–15%). Figure 3-1 presents a generic picture of the typical project costs and relative magnitude over the life cycle of a project including those for renewable energy.

Capital and maintenance costs vary for different renewable energy technologies and may also vary significantly between states and site locations. This section presents thumbnail costs for installation and operations and maintenance for renewable energy technologies that are viable at airports. The data are produced by the DOE's National Renewable Energy Laboratory (NREL)



Source: Federal Aviation Administration

Figure 3-1. Generic life cycle project costs.

updated August 2013 (*59*). As evidenced by the significant changes in renewable energy markets over the past several years, installation costs can vary widely through time based on the maturation of a technology, scale up in production, increased competition, availability of critical natural resources necessary for manufacturing, and other factors. The figures provided will be sensitive to change over time and should be updated if used for more than a screening level analysis (*60*). However, the available information is appropriate for use in conducting initial screening of a project's economic viability.

3.2.1 Wind and Solar

Table 3-1 contains installed costs and O&M costs for solar PV and wind projects produced by NREL. The data are divided up by project size (noted as nameplate capacity) as costs are sensitive to project size. For example, larger projects have more cost efficiencies taking advantage of economies of scale including fixed mobilization costs and reduced transactional costs on a per kW installed basis.

Figure 3-2 presents the installed cost for each technology and project size on a chart including the average project as well as high and low costs using standard deviation.

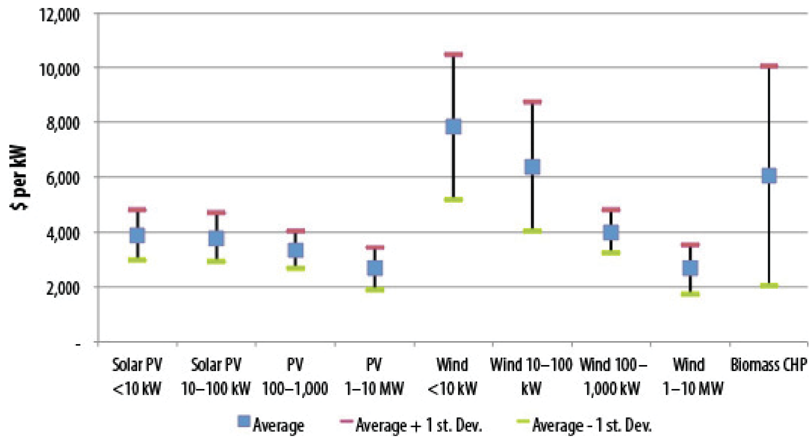
Airports are most likely to consider installing a variety of project sizes for solar PV represented in the data as well as wind projects under 1 MW. As the data show, wind projects in the smaller project sizes have the highest installed costs, which decrease as project size increases. There are a few wind projects at airports that have been installed with a nameplate capacity of greater than 100 kW though projects in the 10–100 kW range are more compatible with aviation uses. Across the board, solar PV projects for all project sizes are demonstrated to be more cost-effective than smaller scale wind projects. The added benefit of solar over wind is that larger scale projects can produce a greater amount of electricity that can be utilized by the airport while small scale wind projects have limited electricity producing capacity.

O&M costs for solar PV and wind are also presented in Table 3-1. These demonstrate another advantage of solar PV over wind in that annual O&M costs for solar PV are 20–40% lower. Given that the solar PV numbers also include tracking systems that have a higher O&M cost and may not be proposed for many geographical locations, the appropriate comparison for solar PV O&M

Table 3-1. Costs for electric generating technologies.

Technology Type	Average installed cost ($/kW)	Installed cost Std. Dev. ($/kW) +/–	Fixed O&M ($/kW-yr)	Fixed O&M Std. Dev. ($/kW-yr) +/–	Useful Life (yr)	Useful Life Std. Dev. (yr)
PV <10 kW	$3,910	$921	$21	$20	33	11
PV 10–100 kW	$3,819	$888	$19	$18	33	11
PV 100–1,000 kW	$3,344	$697	$19	$15	33	11
PV 1–10 MW	$2,667*	$763	$20	$10	33	9
Wind <10 kW	$7,859	$2,649	$28	$18	14	9
Wind 10–100 kW	$6,389	$2,336	$38	$12	19	5
Wind 100–1,000 kW	$4,019	$803	-$33	$13	16	0
Wind 1–10 MW	$2,644	$900	$36	$16	20	7

* PVWatts Calculator (based on 2013 statistics) available from NREL uses $2.60/watt for solar PV above 1MW which is consistent with this data and the latest information.



Source: National Renewable Energy Laboratory

Figure 3-2. Installed cost of renewable energy technologies.

may be on the low end of the standard deviation. Other data presented by NREL show that solar PV O&M for fixed panels are relatively small and can reasonably be $0.02 per kW (see PVWatts calculator) (*61*). Figure 3-3 shows a simple and clean fixed-mounted solar installation at Reno Airport designed on a flat, gravel surface requiring no vegetation management or regular upkeep.

Table 3-1 also presents NREL data for expected project life. These data also support solar PV over wind with solar PV projects having an expected lifespan of over 30 years while small scale wind turbines are in the range of 15–20 years.

3.2.2 Solar Thermal

NREL information on solar thermal is presented specifically for producing hot water. The data for mean installed cost for solar thermal includes both commercial and residential uses. As costs for airports would be most comparable to commercial uses and the commercial data is typically cheaper than residential due to economies of scale advantages, prices for airports would be at the lower end of the range presented. O&M costs are presented as a percentage of the installed cost and only the commercial scale percentage is listed. Flat-plate collectors have been the most common collector for residential water-heating and space-heating installations.

Figure 3-3. Fixed ground-mounted solar PV requires little O&M (Reno Airport ARFF building).

Table 3-2. Costs of solar thermal technologies.

Technology Type	Average installed cost ($/ft²)	Installed cost range ($/ft²) +/–	Annual O&M* (% times installed cost)	Useful Life (yr)	Useful Life Std. Dev. (yr)
SWH, flat plate & evacuated tube	$141	$82	0.5%	31	14
SWH, plastic collector	$59	$15	0.5%	20	10

*This information is for commercial systems, while all other data is a mix of commercial and residential systems.

Plastic collectors concentrate heat from the sun and have increased thermal efficiencies. Thus either system could be applicable to an airport. Table 3-2 summarizes the installed and O&M cost of solar thermal technologies.

3.2.3 Ground Source Heat Pumps

NREL has also presented data on installed costs and O&M for ground source heat pumps (GSHP) provided here in Table 3-3. Capital costs vary significantly depending on geographical location, which dictates land preparation prices and horizontal versus vertical drilling for ground loops. These data can be directly compared to a wood-fired heat system in Section 3.2.4 to assess renewable thermal system options.

GSHP is more costly to install than conventional heating and cooling systems. The benefits are in long-term savings which can be between 20 and 60% depending on the type of GSHP installed and existing price of heat and power (*62*). A recent study focused on the northeast United States provides support for the long-term benefits of converting to GSHP for residential units compared with existing oil boilers and upgrades to natural gas (*63*).

Operations and maintenance costs have been reported to be less than conventional heating and cooling systems (*64*), though start-up and optimization can be more expensive than expected (*65*).

3.2.4 Biomass

Biomass can be used for both electricity and heating. Tables 3-4 and 3-5 present information from NREL respectively on biomass heat and power systems and wood-fired heat systems alone.

As noted in Section 1.2.3, smaller on-site biomass has been demonstrated primarily for heating while biomass electricity generation has been applied to larger utility-scale power plants.

Table 3-3. Costs for ground source heat pump.

Technology Type	Average installed cost ($/ton)	Installed cost range ($/ton) +/–	Annual O&M	Useful Life (yr)	Useful Life Std. Dev. (yr)	Fuel and/or water cost ($/ton)	Fuel and/or water cost Std. Dev. ($/ton) +/–
Ground Source Heat Pump	$7,518	$4,164	$109 (+/– $94)	38	25	$397	$392

Table 3-4. Costs for biomass heat and power systems.

Technology Type	Average installed cost ($/kW)	Installed cost Std. Dev. ($/kW) +/–	Fixed O&M ($/kW-yr)	Fixed O&M Std. Dev. ($/kW-yr)+/–	Variable O&M ($/kWh)	Variable O&M Std. Dev. ($/kWh) +/–	Useful Life (yr)	Useful Life Std. Dev. (yr)
Biomass Combustion Combined Heat & Power*	$6,067	$4,000	$91	$33	$0.06	$0.02	28	8

*Unit cost is per kilowatt of the electrical generator, not the boiler heat capacity.

Table 3-5. Costs for wood-fired heat system.

Technology Type	Average installed cost* ($/kW)	Installed cost range ($/kW) +/–	Fixed O&M ($/kW)	Fixed O&M Std. Dev. ($/kW) +/–	Useful Life (yr)	Useful Life Std. Dev. (yr)	Fuel and/or water cost ($/kWh)	Fuel and/or water Std. Dev. ($/kWh) +/–
Biomass wood heat*	$600	$361	$91	$33	32	8	$0.03	$0.01

* Biomass wood heat converted from thermal energy capacity (Btu/hr).

Table 3-6. Costs for fuel cell power generation.

Technology	Installed Cost	O&M
Fuel Cells	$4.75/watt	$250/kW plus 2% inflation rate

3.2.5 Fuel Cells

The thumbnail NREL data used for the other renewable energy technologies is not available for fuel cells. However, NREL has developed a cost of renewable energy spreadsheet tool (CREST) which includes assumptions for installed and O&M costs for a number of technologies including fuel cells. These costs from CREST are presented in Table 3-6 for consideration (*66*). CREST is reviewed in detail in Section 3.6.2.

3.3 Levelized Cost of Energy

The levelized cost of energy (LCOE) is the cost of owning, installing, and operating the system over its 25-year life. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable O&M costs, financing costs, and an assumed utilization rate for each plant type. The LCOE is based on the annual after-tax cash flow for a grid-connected PV system that either sells all of the electricity it generates at a fixed price to an electricity service provider, or uses all of the electricity that it generates on-site to displace purchases of electricity that would be made from an electricity service provider without the system.

Forecasting the LCOE is difficult because the future cost of fuel and predictions for public policy incentives are uncertain. Table 3-7 presents the LCOE for several renewable energy technologies considered by airports.

For additional insight into some of the cost assumptions behind the LCOE for solar PV, Table 3-8 presents the factors behind the PVWatts calculation.

Table 3-7. Levelized cost of electricity generated for various renewable energy technologies.

Technology	Cost Factor	Source
Solar PV	$0.12/kWh	PVWatts Calculator
Geothermal Heat Pump	$35/millionBTU	Matley, RMI
Wind (600 kW unit)	$0.25/kWh	Cost of Renewable Energy Spreadsheet Tool (CREST)
Fuel Cells	$0.128/kWh	Cost of Renewable Energy Spreadsheet Tool (CREST)

Table 3-8. Assumptions for cost of electricity generated.

Assumption	Value
Debt Amount	100% of installed cost
Loan Term	25 years
Loan Interest Rate	7.50%
Analysis Period	25 years
Inflation Rate	2.50%
Real Discount Rate	8%
Federal Income Tax Rate	28% per year
State Income Tax Rate	7% per year

3.4 Funding Sources

Funding sources include those that are available to airports and their partners. These include tax exempt financing, grants, and third party financing.

3.4.1 Tax Exempt Financing

Airport operators in the United States are overwhelmingly state or local governmental entities with the power to issue debt on a tax exempt basis, thus reducing their financing costs. Therefore, the airport can often finance renewable energy projects that will benefit only the airport itself, such as a solar facility where the power generated will be used entirely by the airport, with the proceeds of tax exempt bonds. However, where the power is to be co-mingled with power provided by a private utility or "sold into the grid" through a net metering arrangement and applied to reduce the airport's overall cost of energy, the private use by the third party utility may prevent the use of tax exempt financing for the project.

Another cost-saving alternative may be for an airport operator to finance the purchase of a specified output of a renewable energy project over a period of years with the proceeds of tax exempt bonds. Such an arrangement is only available to an airport owner that is considered a "utility" acquiring such output for its retail electric customers within its service area. However, some airports are treated under local law as a wholesale utility providing retail electrical service to its tenants at the airport. Thus, such an airport could contract for a guaranteed delivery of power (such as 80% of the expected output of a rated facility) over a specified period (such as 20 years), pre-pay for such energy with proceeds of tax exempt debt, resell such electricity to retail customers within its service area (the airport), and the developer could use such funds to pay costs associated with developing the project. A 2008 Internal Revenue Service (IRS) Private Letter Ruling (PLR) construed these requirements quite liberally, and it is possible that this method of financing acquisition of the output of a renewable energy facility would be accepted by the IRS (*67*).

When an airport is considering constructing a large new facility, such as a terminal or parking garage, or undertaking a significant rehabilitation of such a facility, part of the planning process is often a review of energy requirements and, increasingly, an examination of the potential for incorporating renewable energy sources into the project. Where such renewable sources will be applied solely to heat, cool, light or otherwise provide energy to the project or the airport, especially where such facilities are integrated into a new or rehabilitated airport facility, tax exempt financing for the entire project is often a good source of financing. Because the tax regulations relating to financing such projects are complex, it is often advisable to obtain expert advice at the early stages of planning such a project in order to preserve the ability to finance it in the most advantageous manner.

3.4.2 Grants

Grants available to airports are made through the AIP. There are five current sources of AIP funding that may be used for renewable energy projects. A summary of these programs is presented in Table 3-9. Each program is described in the following subsections. A detailed matrix of the funding programs is provided in Appendix C.

Table 3-9. FAA grant programs.

Program	Program Purpose	Eligible Activities	Eligible Airports	AIP Handbook Guidance
Voluntary Airport Low Emissions Program (VALE)	Reduce sources of airport ground emissions	Airport clean infrastructure and airport dedicated vehicles	Commercial service airports in air quality nonattainment and maintenance areas	Chapter 6, Section 5, p. 6-26, and Appendix S, Table S-1
Airport Energy Efficiency Program (Section 512)	Increase the energy efficiency of airport power sources	Energy efficient on-airport electrical energy production: Solar, geothermal, hydrogen, etc.	Eligible public use airports	Chapter 6, Section 7, p. 6-29, and Appendix S, Table S-1
Airport Sustainability Plans	Making sustainability a core element of airport planning	Sustainability planning, either within an airport master plan or a stand-alone study.	Eligible public use airports	Chapter 3, Section 11, p. 3-53, and Appendix E, E-3, and Appendix S, Table S-1
Zero Emissions Vehicle and Infrastructure Pilot Program	Zero-emission on-road vehicles and supporting fuel infrastructure	Electric drive and hydrogen-fuel vehicles Stand-alone infrastructure included (e.g., recharging stations)	Eligible public use airports in air quality nonattainment and maintenance areas. If insufficient interest, airports in attainment become eligible	Chapter 6, Section 6, p. 6-28, and Appendix S, Table S-1
Airport Improvement Program (AIP) & Passenger Facility Charge Program (PFC)	Airport development, more efficient operations, and reduced costs	Related activities includes energy efficiency, LED lights, recycling, and energy assessments	Eligible public use airports	Entire AIP Handbook

3.4.2.1 VALE Program

VALE is designed to reduce all sources of airport ground emissions. Created in 2004, VALE helps airport sponsors meet their state-related air quality responsibilities under the Clean Air Act. Through VALE, airport sponsors can use AIP funds and Passenger Facility Charges (PFCs) to finance low emission vehicles, refueling and recharging stations, gate electrification, and other airport air quality improvements. It has been used to fund solar PV and GSHP projects. Figure 3-4 shows the required VALE label on a carport solar installation constructed at Albuquerque International Airport using VALE program funds.

3.4.2.2 Airport Energy Efficiency Program

In fiscal year 2012, Section 512 of the FAA Modernization and Reform Act of 2012 (Public Law 112-95) added a program for certain projects that increase the energy efficiency of airport power sources. This legislation simply made these projects eligible for AIP, but did not make these projects eligible for any special set aside funding (including the noise and environmental set aside). As of early 2015, the FAA is in the process of developing guidance to advise airport sponsors on how to apply for the funds. The program includes PPA requirements for solar projects on airport property as well as requirements for attaining and selling RECs.

3.4.2.3 Airport Sustainability Plans

The FAA has been providing eligible airports across the United States with AIP grant funds to develop comprehensive sustainability planning documents. These documents include initiatives for reducing environmental impacts, achieving economic benefits, and increasing integration with local communities, and include identifying opportunities to develop renewable energy. To date, the FAA has provided grants to 44 airports. These grants are helping airports plan for future renewable energy projects and may be used to justify prioritization of future AIP funding requests.

3.4.2.4 Zero Emissions Vehicle and Infrastructure Program

The FAA Modernization and Reform Act of 2012 created a new Zero Emissions Airport Vehicles and Infrastructure Pilot Program. This Pilot Program allows the FAA to award AIP funds for the acquisition of zero emissions vehicles at an airport and for making infrastructure changes to

Figure 3-4. The VALE program funded several airport solar projects (Albuquerque).

facilitate the delivery of energy necessary for the use of these vehicles. These could incorporate renewable energy charging options for airports.

3.4.2.5 AIP and PFC Program

Airports can use the AIP and PFC funding programs to include renewable energy projects as part of larger infrastructure programs and apply AIP and PFC funding for the renewable energy infrastructure. These could include adding renewable energy to a proposed terminal, parking garage or other landside building project.

3.4.3 Third Party Financing

Renewable energy projects can be financed in a number of different ways. However, they are often “project financed” on a non-recourse or limited basis, meaning that the construction of the project is financed off the balance-sheet of the developer or sponsor. In a non-recourse, or “project financed” project, the facility itself, including all of the rights to the revenue derived from the project, is used as collateral for the loan.

In addition to debt finance, the renewable energy industry typically makes use of the various tax credits available to renewable energy developers. These include the production tax credit (PTC) for wind projects (which expired for projects commenced after December 31, 2013), and the investment tax credit (ITC), which has been widely used for solar projects. The ITC for solar is essentially worth 30% of qualifying expenditures used in developing the solar project though it will decrease to 10% on December 31, 2016. Other technologies such as fuel cells and small wind turbines are also eligible for the ITC at 30% and geothermal is eligible at 10%. Often, developers of renewable energy projects cannot use these credits themselves as they do not have enough taxable income to offset with the tax credit. Therefore, solar projects typically attract investment from larger financial institutions as joint venture partners that can use the tax credits and effectively monetize their benefit.

Essentially, no matter the source of third-party financing, financing parties for renewable energy projects will want to ensure that the project has an uninterrupted revenue stream for the period of their investment and that there are unlikely to be unexpected cost issues during that period. Therefore, a carefully drafted PPA is a critical element of the financing and development of most renewable energy projects.

3.5 Financial Metrics

There are a variety of financial metrics that can be used to assess the viability of a particular project. A few of the most common ones for airport projects are described below.

3.5.1 Benefit Cost Analysis

The FAA announced policies in 1994 that establish the requirement for benefit cost analysis (BCA) to demonstrate the merit of capacity projects for which airport sponsors are seeking AIP discretionary funds. It subsequently produced guidance for airport sponsors in conducting such analyses (*68*).

FAA considers capacity projects to include those involving new construction or reconstruction of airport infrastructure intended to accommodate or facilitate airport traffic. The FAA policy requiring BCA does not apply to projects undertaken solely, or principally, for the objectives of safety, security, conformance with FAA standards, or environmental mitigation. The

BCA must be prepared for projects with capacity projects requesting AIP funds of $5 million or greater or any capacity project requesting a letter of intent (LOI) from the FAA.

The BCA is used to justify the spending of public funds administered under the AIP program that has historically been funded through taxes imposed on aviation systems users. As such, all benefits and costs affecting the aviation public or directly attributable to aviation should be considered and evaluated in the BCA. Such benefits may include benefits realized in the form of monetary gains (e.g., lower operating costs), reductions in non-monetary resources (e.g., personal travel time), or mitigation of environmental impacts. Therefore, the BCA considers not just cash benefits and costs, but also greater benefits to the proposed action on the flying public. Types of benefits from aviation projects include increase in capacity (and reduction in delays), improved safety and security, achievement of design standards, enhanced environmental benefits like noise reduction, and improvements to inter-terminal transportation.

Evaluating renewable energy projects in the content of BCA can be challenging, given the strong emphasis of demonstrating that the benefits directly accrue to the aviation system and public. Renewable energy projects can provide immediate environmental benefits. They can also provide financial benefits in the form of cost savings over the long-term, but payback periods can be longer than for other energy cost saving benefits associated with improved energy efficiency. Renewable energy can also be part of a plan to modernize the grid and provide redundancy and resiliency, providing greater power reliability during unforeseen events. These types of benefits have been gaining some credence recently in the wake of increased frequency of hurricanes and coastal storms.

3.5.2 Net Present Value

Net Present Value (NPV) is the most widely used and theoretically accurate economic method for selecting investment alternatives, and should be used for all analyses prepared for the FAA's consideration. The NPV method requires that the alternative meet the following criteria to warrant investment of funds:

- Have a positive NPV; and
- Have the highest NPV of all tested alternatives.

The first condition insures that the alternative is worth undertaking relative to the base case (i.e., existing conditions) in that it contributes more in incremental benefits than it absorbs in incremental costs. The second condition insures that maximum benefits are realized when evaluating against the baseline condition. Because of its strict focus on financial benefits and less on non-financial, it is often considered a supplemental tool for airport projects.

3.5.3 Internal Rate of Return

The internal rate of return (IRR) is defined as the discount rate that equates the present value of the stream of expected benefits in excess of expected costs to zero. In other words, it is the highest discount rate at which the project will not have a negative NPV. To apply the IRR criterion, it is necessary to compute the IRR and then compare it with an OMB-prescribed 7% discount rate. If the real IRR is less than 7%, the project would be worth undertaking relative to the base case.

3.5.4 Payback Period

The payback period measures the number of years required for net undiscounted benefits to recover the initial investment in a project. One characteristic of this evaluation method is that it favors projects with near-term (and more certain) benefits. However, the payback period method does not consider benefits beyond the payback period. Nor does it provide information on whether an investment is worth undertaking in the first place.

3.6 Modeling Tools for Renewable Energy

A number of renewable energy modeling tools are available to the public that can help users assess the potential viability of a renewable energy system for a particular project location. Models can integrate site-specific information on expected renewable energy generation capacity based on geography as well as basic financial assumptions for typical renewable energy projects. The user can insert some baseline information on energy consumption levels and unit pricing to better evaluate the financial feasibility of a project at a specific building or load area.

Tools produced by federal agencies have broad-scale applicability and provide generic information with some site-specific customization. Two often-used tools—PVWatts and CREST—were developed by NREL and are described in this section. A third model, EP&CBT, produced under *ACRP Report 110* to evaluate the cost and benefit of airport sustainability projects, is also presented.

3.6.1 PVWatts

The PVWatts Calculator is a web application developed by the NREL to estimate the electricity production of a grid-connected roof- or ground-mounted PV system based on a few simple inputs that allow homeowners, installers, manufacturers, and researchers to easily gauge the performance of hypothetical PV systems. To begin using the calculator, the user simply types in the address or geographic coordinates for a potential PV system. Based on the location, PVWatts automatically identifies applicable solar resource data for the system, which it translates into forecasted electricity generation. To represent the system's physical characteristics, PVWatts requires a value for five inputs:

- The system's DC size,
- Array type,
- A DC-to-AC derate factor,
- Tilt angle, and
- Azimuth angle.

Using an hour-by-hour simulation over a period of one year, PVWatts estimates the annual and monthly electricity production of a PV system, as well as the cost and value of the electricity produced by the system. The cost of electricity estimates are based on whether the PV system is on residential or commercial property, its installation cost, and the retail cost of electricity. Airport users should apply the commercial property case.

PVWatts is suitable for very preliminary studies of potential locations for PV systems using typical crystalline silicon modules. However, the production estimates do not account for many factors that are important in the design of a highly efficient system and therefore should be used only as a screening tool to be followed up by a site-specific analysis.

3.6.2 Cost of Renewable Energy Spreadsheet Tool

CREST is an economic cash flow model designed by NREL to allow policymakers, regulators, and the renewable energy community to assess project economics, design cost-based incentives (e.g., feed-in tariffs), and evaluate the impact of various state and federal support structures.

CREST is a suite of five analytic tools, for solar (photovoltaic and solar thermal), wind, geothermal, fuel cells and anaerobic digestion technologies.

CREST models are designed for use by state policymakers, regulators, utilities, developers, investors, and other stakeholders. The models allow users:

- To estimate the Year One cost of energy (COE) and LCOE from a range of electricity generation projects;
- To experiment with the process of setting of cost-based incentive rates;
- To observe the effects of different economic drivers on a given renewable energy project's COE and LCOE;
- To comprehend the relative economics of generation projects with differing characteristics, such as project size, resource quality, location (e.g., near or far from transmission) or ownership (e.g., public or private).

3.6.3 EP&CBT Modeling Tool

3.6.3.1 Model Overview

ACRP Report 110: Evaluating Impacts of Sustainability Practices on Airport Operations and Maintenance provides an EP&CBT for evaluating sustainability practices considered by airport sponsors. The tool has the ability to look at both baseline and new practice costs in order to evaluate the cost benefit of the initiative. The EP&CBT model was developed to include the O&M costs of a proposed sustainability practice as part of the life cycle assessment when determining the potential cost benefits. The EP&CBT model is designed to evaluate a variety of sustainable practices related to:

- Water conservation;
- Energy conservation;
- Waste management;
- Consumables and materials; and
- Alternative fuels.

The EP&CBT is a user friendly tool that does not require a lot of training or data. An analysis can be completed in less than an hour for any sustainable initiative, and provides practical results of likely impacts of the sustainable initiative. The tool was developed in Microsoft Excel®, which is familiar to many users in organizing data and developing spreadsheets and cost estimates. The tool is flexible and can be used for a variety of sustainable initiatives, including renewable energy projects like solar, geothermal, and wind. The goal of the EP&CBT is to produce results that help sponsors with planning and decision making when comparing baseline conditions to the proposed sustainable initiative, including total net costs or savings of the proposed practice, cumulative net present value over the analysis period as well as the return on investment over the period.

The developers of the tool worked with numerous airports, both large and small, where sustainability projects had already been initiated. These included Albuquerque and Fresno, which host solar PV facilities; this information was used to validate the information it can generate for renewable energy assessments. The intent of working with the airports was to evaluate a large variety of project types as well as refining the model based on feedback from the airports in order to provide a tool that would be useful to airport planners.

The model allows the user to input baseline and future costs for a range of years associated with the sustainable initiative for three categories:

- Startup costs
- Operational and maintenance costs
- End of life costs

The model takes all the costs entered by the user and creates output charts and graphical summaries of key impacts of the sustainable initiative such as NPV, total or net cost savings, and return on investment (ROI). A detailed budget view can also be generated, summarizing costs for:

- Personnel;
- Materials and supplies;
- Contractual services;
- Operational expenditures;
- Capital outlay;
- Interdepartmental; and
- Other

This can be a very useful way of viewing the costs in a standard method that can summarize the monetary impacts for key components to the initiative and can be useful when trying to develop a budget for the initiative. The graphical output provides cost summaries and graphics of key cost metrics including:

- Total O&M costs;
- Total net benefits;
- Cumulative NPV over time;
- ROI; and
- Break-even point.

To demonstrate the tool's capability and applicability to renewable energy projects, a case study for solar PV is provided. In this case, the EP&CBT was used to determine cost metrics such as return on investment, payback period, utility impacts, and lifecycle costs using assumed costs and parameters typical for a 500 kW solar PV project.

3.6.3.2 Case Study Solar PV

A case study was prepared to show the EP&CBT model's capability of evaluating the cost benefits of a proposed renewable energy technology. The example is a hypothetical 500 kW roof mounted solar project at an airport on the mid-Atlantic coast. The project could provide up to two thirds of the airport's electrical needs in the terminal at an expected total cost of $2.3M. The project would require an electrical grid interconnect to hook up to the terminal electricity connection and the majority of the costs would consist of the solar PV panels and installation. In addition to the panel and installation costs, project costs included the interconnection study, inverter replacement, O&M, solar glare and energy assessment, administrative/legal support, and a consultant engineer to provide project oversight for the airport. Other miscellaneous fees such as workman's compensation, design fees and permits, and liability are typically included in the installation costs.

For this analysis, the default discount rate of 7% was used which takes into account the time value of money. The discount rate is used in the NPV calculation to provide a present value of cash flow in the future. Also input to the model were the baseline electricity costs over 20 years, assuming the electricity usage would be the same but the costs of the electricity would increase by 5% each year.

For the net benefit electricity costs from the solar PV project, the NREL PVWatts program was used to estimate the electrical generation from a proposed 500 kW system in the Atlantic City area, assuming a 180 degree azimuth and a 20 degree tilt angle. It was estimated that the system could generate 667,712 kWh of electricity per year. Over the 20-year life of the project, the amount of electricity generated by the project (assuming a 0.7% reduction in efficiency annually as the system ages) is estimated at 12,464,948 kWh. Based on the estimated annual cost of electricity, the system could save the airport approximately $1,903,243 over the 20 year period. As one of the many tasks when evaluating a new project, an airport sponsor needs to know from a business perspective, what the ROI and break-even point of this project will be once all the costs are factored in.

To assist other airport sponsors in filling out the necessary inputs for a typical solar project, guidance based on a review of other solar projects and installation costs has been provided. The EP&CBT model was run with the following inputs and assumptions in order to calculate the ROI and the project break-even point:

- System Installation Costs–$2,025,000
- Future Inverter Replacement–$150,000
- Interconnection Study–$25,000
- Solar Glare Analysis–$4,000
- Energy Assessment–$20,000
- Administrative and Legal Support–$70,875
- Labor Operations and Maintenance–$5,296
- Consultant Fees–$75,000

It should be noted that there could be other costs associated with a solar system not included here, such as landscaping or paving costs, canopy costs if located over a parking garage, feasibility studies, etc. Based on research, the eight parameters listed are the most common costs associated with developing a roof mounted system at an airport.

As shown in Figure 3-5, the results from the EP&CBT model for the hypothetical solar project over a 20 year period show the total installation and O&M costs of the project at $4,379,038, the

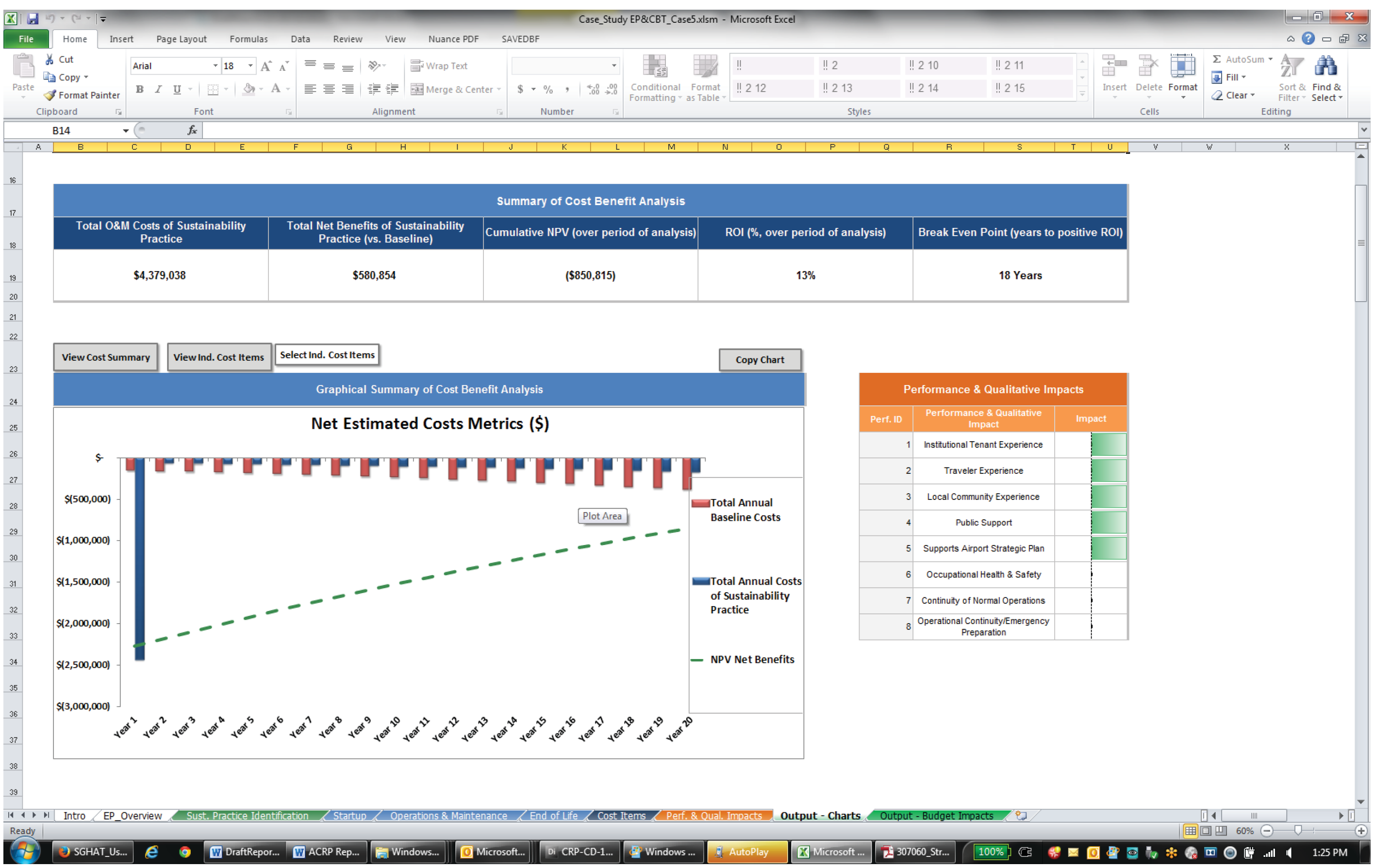


Figure 3-5. Cost benefit analysis.

total net benefits of the project at $580,854, the ROI (percent over period of analysis) was 13% and the payback period was 18 years. The performance and qualitative impacts of the project were deemed positive in terms of institutional tenant experience, the traveler experience, local community experience and would have both public and employee support. Figure 3-6 shows the baseline electricity costs compared with the future electricity costs with the solar PV project. It was estimated over the 20 year lifespan of the project, a total of approximately $1.9 million in avoided electrical costs could be realized by the project. Without the project, the airport could pay up to $4.9 million in electricity cost over the 20 year period.

This is just one example of how the tool can be used to evaluate a renewable energy project and determine the cost effectiveness of the proposed alternative. The tool is flexible for a variety of project types and can also include end of life (i.e., decommissioning, removal and disposal) costs for the project if those costs are known. The tool is easy to use and provides output charts for key economic cost metrics, which can help the airport sponsor when evaluating the economic benefits of a proposed renewable technology over the life of the project.

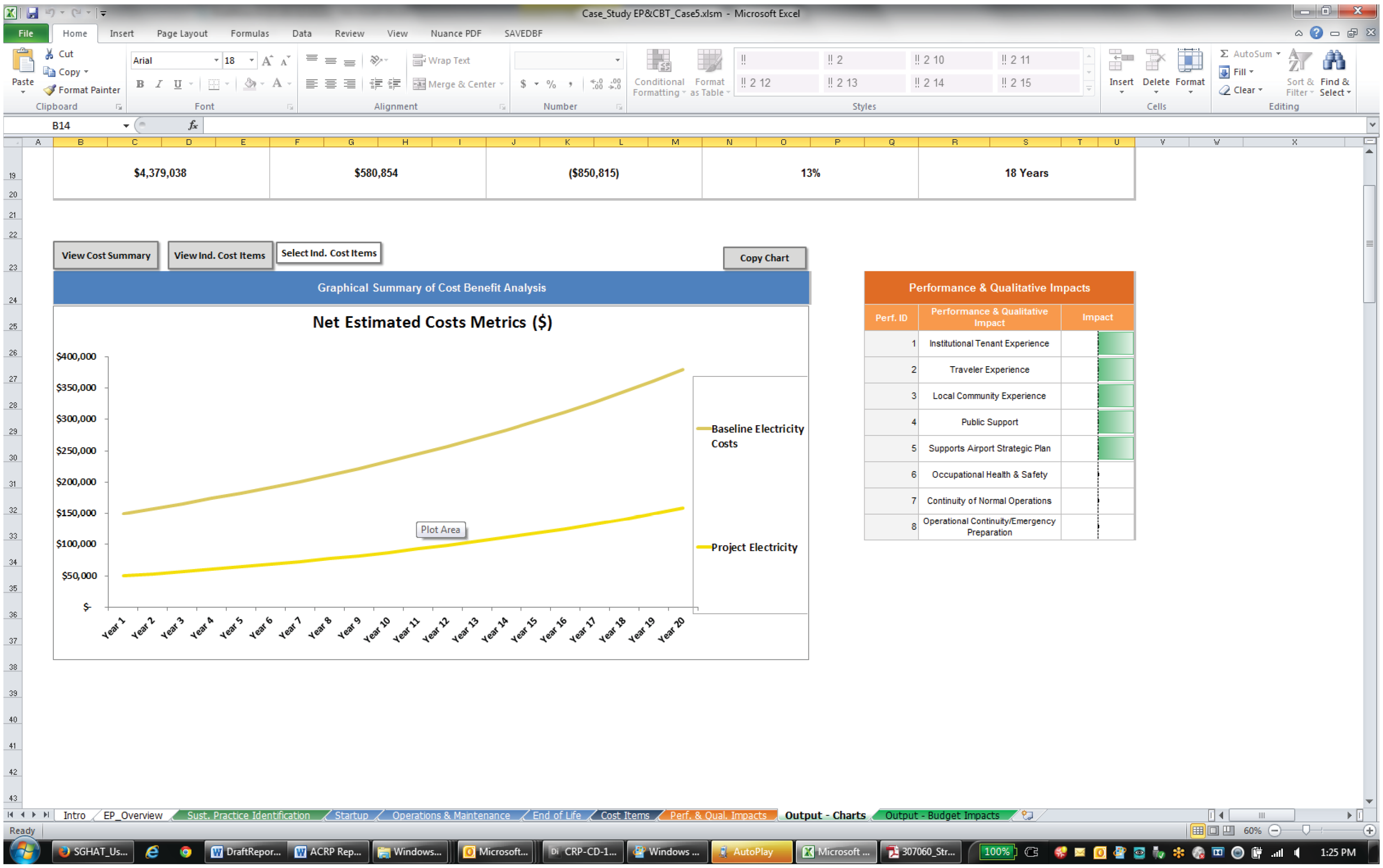


Figure 3-6. Model output: electricity cost baseline vs project costs.

CHAPTER 4

Implementing Airport Renewable Energy Projects

Renewable energy projects are implemented in ways similar to other airport projects. The projects can affect other parties requiring stakeholder coordination and public outreach. To be successful, the projects should:

- Be publicly bid and qualified private partners selected;
- Obtain regulatory approvals; and
- Be well managed to be successful.

However, there are particularities associated with renewable energy projects.

This chapter describes the key implementation steps and provides specific examples from other renewable energy projects to help airports in administering future projects.

4.1 Stakeholder Coordination

Elements of the stakeholder process include public review during planning and permitting, and education and outreach throughout the life of the project.

4.1.1 Public Review

Airports convene regular public meetings to discuss airport activities and authorize future work as necessary. Airport sponsors can use these regular meetings to introduce the project concept and provide status reports throughout the project life during planning, construction, and operations. These meetings will afford the airport with a high level of transparency and help identify any issues that may be raised by neighbors, tenants, or other affected parties. Should issues be raised, the airport can respond to the issue either immediately by answering questions or at a future meeting should additional research be required. The public engagement will help to solidify support for the project.

Engagement with local community groups may often be addressed adequately through the regular airport public meetings. However, in some circumstances, the airport may choose to engage these groups through separate meetings to ensure that their members are sufficiently informed about a particular airport project or activity. In other instances, individual meetings may be arranged after some initial level of information exchange occurs at the regular airport meeting to expand the level of outreach. Typically, renewable energy projects are not likely to cause a concern for neighbors given their relatively non-obtrusive nature. Given its large size, a utility-scale wind turbine proposed on airport land is a logical exception and might warrant additional outreach depending on its proximity to residential areas.

Other stakeholders such as tenants, government agencies, and environmental groups may have interest in the proposed renewable energy project. Tenants may have questions about the potential effects of the project on their activities and/or lease agreement. Interaction with other government agencies may occur as part of regular intergovernmental coordination and cooperation processes. Environmental groups may be interested in particular resource impacts issues (e.g., birds and wind turbines) or carbon mitigation benefits of the project. Involvement of these groups will depend on the type of renewable energy project and the airport's relationship with the organization. They may also be triggered by communication at the regular airport public meetings.

4.1.2 Education and Outreach

Public education and outreach associated with a renewable energy project is a good vehicle for enhancing communications between the airport and the public. Renewable energy projects have a broad level of interest. Information can readily be provided by the airport to the public about the project during construction and operations to build a positive following. It is best to utilize existing communication tools and practices and integrate the communication of the renewable energy project to those rather than creating new forums to be managed, though there may be exceptions. Some options to consider are as follows.

4.1.2.1 Website

The airport can build a project webpage to provide interested parties with basic information on the project including how it works, why it was constructed, and anticipated benefits. Updates can be included periodically along with links to social media that update automatically based on activity levels. These forums can also engage community comments and be a way to collect feedback on successful implementation of the project and lessons learned.

4.1.2.2 Press Releases

Airports regularly issue press releases on their activities that will be picked up and published in local media and industry publications. Renewable energy projects are of interest to the public and therefore often receive wide circulation. Therefore, airports should put out press releases about the project at particular milestones including after formal announcement to proceed with the project, at the start of construction, and at the commencement of operations.

4.1.2.3 Newsletters

Existing newsletters sent to community groups, tenants, and interest groups should include regular communication of the project and its benefits. If this is a regular communication tool used by the airport, brief articles and updates can help keep readers informed and engaged about the project.

4.1.2.4 Information Kiosk

Many renewable energy projects can be developed with an information kiosk to provide visitors with information on the project and its benefits. Kiosks can be used to communicate broader information about related issues such as sustainability to provide context for the renewable energy project. The kiosk is an effective way to display real-time electricity generating data about the system which, if located on the building roof or remote section of the airfield, might not otherwise be visible. The data can also be communicated in ways that are more understandable to the general public. Examples include the system generates enough electricity to power X number of homes, or reduce enough pollution to remove Y number of cars from the road. The kiosk can also provide static information about the system's specifications. An example of an information kiosk located at Albuquerque International Airport's (ABQ) terminal is shown in Figure 4-1.

102 Renewable Energy as an Airport Revenue Source

Figure 4-1. Solar project information kiosk in Albuquerque airport terminal.

4.2 Partner Selection

Renewable energy projects have different business structures. Regardless, airports need to follow a public procurement process to select a knowledgeable private partner that can help the airport implement the project. Airports can work with their regular airport planning and engineering firm to prepare the bid documents; however, the structure of the bid process will depend on the role of the project partner. This section first describes the types of partners that could be procured and then describes the primary steps in the procurement process. Appendix F also includes three RFPs that were issued over the past year by airports for renewable energy projects.

4.2.1 Types of Private Partners

There are several different types of services that airports may procure in implementing and operating a renewable energy project.

4.2.1.1 Consultant

Airports may wish to conduct an evaluation of the renewable energy opportunities specific to their land and buildings. This would be a follow-up step to an initial evaluation using some of the modeling tools presented in Section 3.6. In such a case, the airport may procure for the services of a consultant to develop a renewable energy strategy or to conduct a renewable energy siting study. This work may be logically conducted as follow-up to a sustainability master plan or as part of a major multi-year airport renovation project. One benefit of such a study is that it can provide the airport with an independent roadmap on how to proceed with a renewable energy program as an exhibit to facilitate discussion.

4.2.1.2 Contractor

If the airport is going to own the renewable energy facility, then it needs to bid for the services of an engineering, procurement, and construction (EPC) contractor to help it develop the project. For renewable energy installations, it is common to hire a turnkey installer who provides all of the equipment, installs the project, and commissions it prior to operation. For small solar PV projects, all of these services may be provided by a single electrical contractor. For large projects like a utility-scale wind turbine, there will likely be a general contractor who will oversee all of the work including site preparation, foundation design and installation, delivery of equipment to the site, design and construction of roadways, and integration of electrical infrastructure. The contractor and the equipment manufacturer will also stay involved with the project after construction to optimize the system's operations and conduct initial stages of the maintenance program. Depending on the contracting arrangement and particulars of the warranties, these partners may remain involved in longer term O&M activities.

4.2.1.3 Third Party Developer

If the airport seeks to lease property to a private entity to build, own and operate a renewable energy system, then it needs to select an experienced energy developer through a procurement process. The structure of the bid documents will differ if the airport is just leasing the land or also buying the electricity. When the airport is just leasing the land, it will specify in the bid package the expected type of development and the available area, and request a qualified bidder and proposed lease price on a per acre basis. When the airport is also buying the electricity from the third party developer, it will require bidders to provide an annual cost for electricity through a power purchase agreement.

4.2.2 Procurement Process

The procurement process is where the services required for the project are described and the eligible bidders are solicited to present their qualifications to complete the work and cost for the services. This is typically conducted through the issuance of a request for proposals (RFP) or a request for qualifications (RFQ). It is important that the solicitation package accurately and effectively communicate the services required so that the responses to the RFP/RFQ address the need. The key elements of the procurement process are described as follows.

4.2.2.1 Defining Project Scope

The project scope focuses precisely on the services for which the airport seeks a partner and intends on entering into a contract. There are several major categories of projects for which airports may require services.

First, the airport may seek a consultant to assess the feasibility of a renewable energy project. The project scope for such work will include evaluating the availability of renewable energy resources at the project site; reviewing available land and building locations, assessing potential candidate sites for airspace compatibility; preparing an economic analysis and considering available financing options; and preparing recommendations for proceeding with next steps.

The follow-on project scope will be defined by the conclusions of the feasibility study. If the airport decides that it will own the facility itself, then it will issue a project scope of work for turnkey services to engineer, design, and construct the project. If the airport decides that it wishes to lease property to a private entity to build, own, and operate a renewable energy facility, then it will issue a project scope that details the characteristics of the project location that will be leased and type of facility that will be allowed. If the airport also seeks to purchase power from the facility, the scope will also describe the minimum term of the intended purchase and provide a form of a contract that will govern the power purchase.

In all cases, it is important that the project scope of work accurately and effectively describe the services that are sought. This will ensure that the bids that are received are comparable and address the services required by the airport.

4.2.2.2 Writing and Publishing the RFP

The project scope of work is a fundamental element of the RFP as it details what services are sought. However, there are other important aspects of the RFP, including providing direction to bidders, to ensure that an eligible and qualified bidder can be selected.

First, the RFP will provide general information about the airport, the administrative contact for the RFP, and context for the project. This will give bidders a broader understanding of the project. RFPs can also specify eligibility requirements and provide guidance on types of qualifications. For a renewable energy project, the RFP might specify that bidders must have installed a minimum number of renewable energy facilities to meet the eligibility requirement.

The RFP may then specify the organization of the response to ensure that it can easily compare the information that it receives. It will also describe the evaluation criteria so it is clear to the bidders what aspects of the response will be important and the weight of the review if an evaluation score is also provided.

The RFP will include a schedule for submission and evaluation. Once the RFP is published, there should be no direct communication between individual bidders and the airport to ensure that information about the bidding process is distributed openly and no preferential treatment is provided. Thus, bidders are often provided a forum and deadline for submitting questions to the airport, which are distributed with answers to all interested parties after the deadline. Deadline time and delivery location are specified and absolute to ensure that no single proposal receives any accommodations. The RFP may describe a process for short-listing bidders and/or interviewing a subset of bidders that are most qualified.

A legal notice requesting proposals is often published in local newspapers and posted on the airport's website on a page listing all of its current bid opportunities. The notice will often be distributed broadly through industry organization online newsletters, websites that list bid opportunities, and through social media.

4.2.2.3 Reviewing Proposals and Selecting the Contractor

Once the airport receives the proposals, they are reviewed by an internal review team with airport expertise in planning, managing, and financing the airport activities. The reviewers will initially assess the eligibility of the bidder and completeness of the response. Then the reviewers will assess the adequacy of the response relative to the evaluation criteria. Typically, the technical

> Appendix F includes three RFPs issued by airports for renewable energy projects. Each RFP addresses a different business structure. F-1 is from Nashville (BNA) and it seeks a design and construction firm to provide a geothermal system that will be owned by the airport. F-2 is from Indianapolis (IND) and is an example of a straight land lease to a third party solar developer. F-3 is from Santa Barbara Airport (SBA) and is for a third party to build, own and operate a solar facility and execute a power purchase agreement with the airport to sell all of the electricity generated.

proposal and cost proposal will be reviewed and evaluated separately. In that way, the airport can determine the most technically qualified bidders without partiality to amount of the proposal, and then separately list the costs of each bid to select the bidder who is most technically qualified for the appropriate fee. The selected bidder will be notified and bid selection confirmed subject to negotiation of terms.

4.3 Contracting Process

4.3.1 Procurement for Construction

Depending on the project, construction arrangements for a renewable energy project may be divided between supply agreements with equipment providers and “balance of plant” agreements with contractors who build the projects. Alternatively, a contractor will “wrap” all supply, procurement, and construction of the renewable energy project into its proposal.

No matter how it is structured, a developer will typically look for the various contractors to provide completion guarantees, performance guarantees, and equipment warranties.

This means that some combination of the contractor or equipment provider will (1) guarantee to complete construction of the project on time and that upon completion of construction the project will perform and produce energy at or above some pre-determined criteria; (2) guarantee that the project will perform at some pre-determined level for a period of time; and (3) warrant that the equipment and the workmanship will be free from defects.

Typically, a developer will look to these contracting entities to provide some sort of guarantee of performance security to ensure that there is credit standing behind these obligations. Where applicable, the Power Purchase Agreement (PPA) generally includes performance standards such as delivery of a required minimum amount of electricity over a stated period of time and limitations on the amount of time that a facility can be inoperative in a given period.

Airport operators should also note that affixing renewable energy projects to existing airport facilities, such as mounting a PV system on the roof of an existing terminal, can void certain existing warranties, such as a roofing warranty. Where new facilities are being affixed to existing facilities, the airport operator may wish to negotiate a risk shifting arrangement with the developer to ensure that if a warranty is compromised by the project, the developer is responsible for making repairs made necessary by the development of the renewable energy facility.

4.3.2 Procurement for Power Purchasing

Another issue that an airport will need to consider before entering into a PPA or another arrangement with a developer of a renewable energy facility at the airport is whether state or local law requires the airport operator to comply with applicable procurement or public bidding laws. Airports currently purchase power either through their utility service company or in blocks from a power broker. These purchases are customarily not subject to a public bidding process but rather overseen through annual budget management and approval by the airport’s governing authority. Time requirements for public procurement are not consistent with the need to supply power. Long-term contracts, however, are planned investments and there may be state or local laws that trigger a public procurement.

In most cases, entering into a PPA for a renewable energy project located on airport land will be subject to public procurement through the transfer of property use rights necessary for the private party to develop the project. The airport must go through a procurement process to lease or sell land to ensure that it receives the best available financial offer from the most qualified bidder. If the airport is only leasing the land, then the financial benefit is provided by a proposed price per unit area over a designated term that must at a minimum meet the fair market value analysis prepared independently by the airport. If the financial benefit of the project is determined by the PPA price and term, then the procurement for the property rights transfer will include a bid for the PPA.

To ensure that the airport receives comparable bids that meet the needs of the airport, the bid package needs to provide specific information about the minimum requirements of the PPA, such as its term, and will usually include a form agreement for the PPA to ensure during the bidding process that the bidders will agree to it. The PPA should also conform to the latest FAA guidance to ensure the airport sponsor is receiving fair market value and will not be penalized should the system not produce enough power.

4.4 Regulatory Coordination and Processes

The process of implementing the primary regulatory procedures—NEPA, FAA Land Use Review, and FAA Obstruction Evaluation—is summarized in the following sections.

4.4.1 NEPA Review

The application of NEPA should be coordinated closely with the FAA ADO early in project planning. As described in Section 2.6.1, NEPA review will vary based on the extent of the proposed project development activity. As it is FAA's responsibility to ensure that the proposed project has been implemented consistent with the NEPA regulations, the airport needs to work with the FAA to ensure that the FAA has obtained sufficient information to demonstrate compliance.

Many renewable energy projects will meet the FAA's categorical exclusion (CATEX) thresholds. As the first step in determining if the project is eligible for a CATEX, the sponsor needs to complete the Categorical Exclusion Justification Package which can be found on the FAA's website under its Draft FAA Order 1050-1F (*69*). Preliminary evaluation should be conducted to determine if the project is consistent with any of the FAA's CATEX listed actions. Those actions, which have been identified for past CATEX's for renewable energy projects, are listed in Table 4-1 along with a new CATEX specific to solar and wind power projects that are part of the Draft FAA Order.

A project that meets this list of categorically excluded actions is not automatically exempt from environmental review under NEPA. The responsible FAA official must also review Paragraph 5-2, Extraordinary Circumstances, before deciding to categorically exclude a proposed action. Extraordinary circumstances are factors or circumstances in which a normally categorically excluded action may have a significant environmental effect that then requires further analysis in an EA or an EIS. Impacts that may be determined to be classified under extraordinary circumstances include the following: historical and cultural resources; natural resources and wildlife; and inconsistency with local planning, traffic congestion, noise, air quality, water quality, and cumulative impacts. The CATEX documentation will need to address each of these issues.

4.4.2 Federal Airport Obligations

The FAA has broad oversight at federally obligated airports. The obligations arise from the conveyance of land or from grant agreements entered under federal legislation listed in Table 2-1. To comply with its obligations, airport sponsors must ensure during implementation that the renewable energy project is consistent with the following standards.

Table 4-1. FAA categorical exclusions for renewable energy projects.

Section #	Section Name	Description
5-6.4 (n)	Categorical Exclusions for Facility Siting, Construction, and Maintenance.	Minor expansion of facilities including the addition of equipment on an existing facility where no additional land is required, or when expansion is due to remodeling of space in current quarters or existing buildings.
5-6.4 (r)	Categorical Exclusions for Facility Siting, Construction, and Maintenance.	Purchase, lease or acquisition of three acres or less of land with associated easements and rights-of-way for new facilities.
5-6.4 (aa)	Categorical Exclusions for Facility Siting, Construction, and Maintenance.	Upgrading of building electrical systems or maintenance of existing systems, such as painting, replacement of siding, roof rehabilitation, resurfacing or reconstruction of paved areas, and replacement of underground facilities.
5-6.3 (i)	Categorical Exclusions for Equipment and Instrumentation.	Approval of an ALP, federal financial assistance for, or FAA projects for: the installation of solar or wind-powered energy equipment, provided the installation does not involve more than three total acres of land (including the land needed for easements and rights-of-way associated with building and installing the equipment, and any trenching and cabling that would connect the installed solar or wind equipment to other parts of the airport or an existing electrical grid. Construction contracts or leases for this equipment must include requirements to control dust, sedimentation, stormwater, and accidental spills).

4.4.2.1 Grant Assurances

Compliance with grant assurances will be reviewed for any airport renewable energy project. If the airport is using AIP grants, the review of grant assurance compliance will be part of the FAA's review and approval of the airport sponsor's AIP application. If there is no FAA grant funding because the project will be implemented by a third party, the grant assurance review will be conducted as part of the FAA's review of the property rights transfer.

4.4.2.2 Airport Layout Plan

ALPs need to be updated every 5 years or longer if there have been no significant alterations at the airport. Interim changes to the ALP may be approved by the FAA; these are often referred to as "pen and ink" changes. Modifications to the ALP are considered a federal action and trigger the FAA's evaluation to ensure that the change is consistent with NEPA. When a renewable energy project is proposed at an airport, the sponsor will need to consult with the FAA to determine if an update to the ALP is required. The FAA's Solar Guide recommends that solar facilities proposing to occupy a new footprint area need to be shown on the ALP while those that are collocated with an existing building do not (*70*). As more airports incorporate sustainability and renewable energy planning into their master plans, the FAA may see more ALPs with renewable energy uses designated in non-aeronautical use areas, which will facilitate FAA review of individual projects.

4.4.2.3 Fair Market Valuation

As part of the FAA's review of proposed lease agreements, it will evaluate information provided by the airport sponsor to document that the value of the lease meets grant assurances associated with the airport obtaining FMV. FMV determinations for renewable energy projects will be different than for aeronautical uses such as hangar lease or non-aeronautical uses such as commercial space, and therefore, should not be compared to those uses. Typically, it will not be in the airport's best economic interest to lease land for renewable energy that could be used for higher value uses. Demonstration of FMV will be similar to those obtained for agricultural leases. A public bidding process for a renewable energy project lease that demonstrates competitive price for the specified use with some comparison to other comparable alternatives (such as an agricultural lease) should suffice.

4.4.3 FAA Obstruction Evaluation

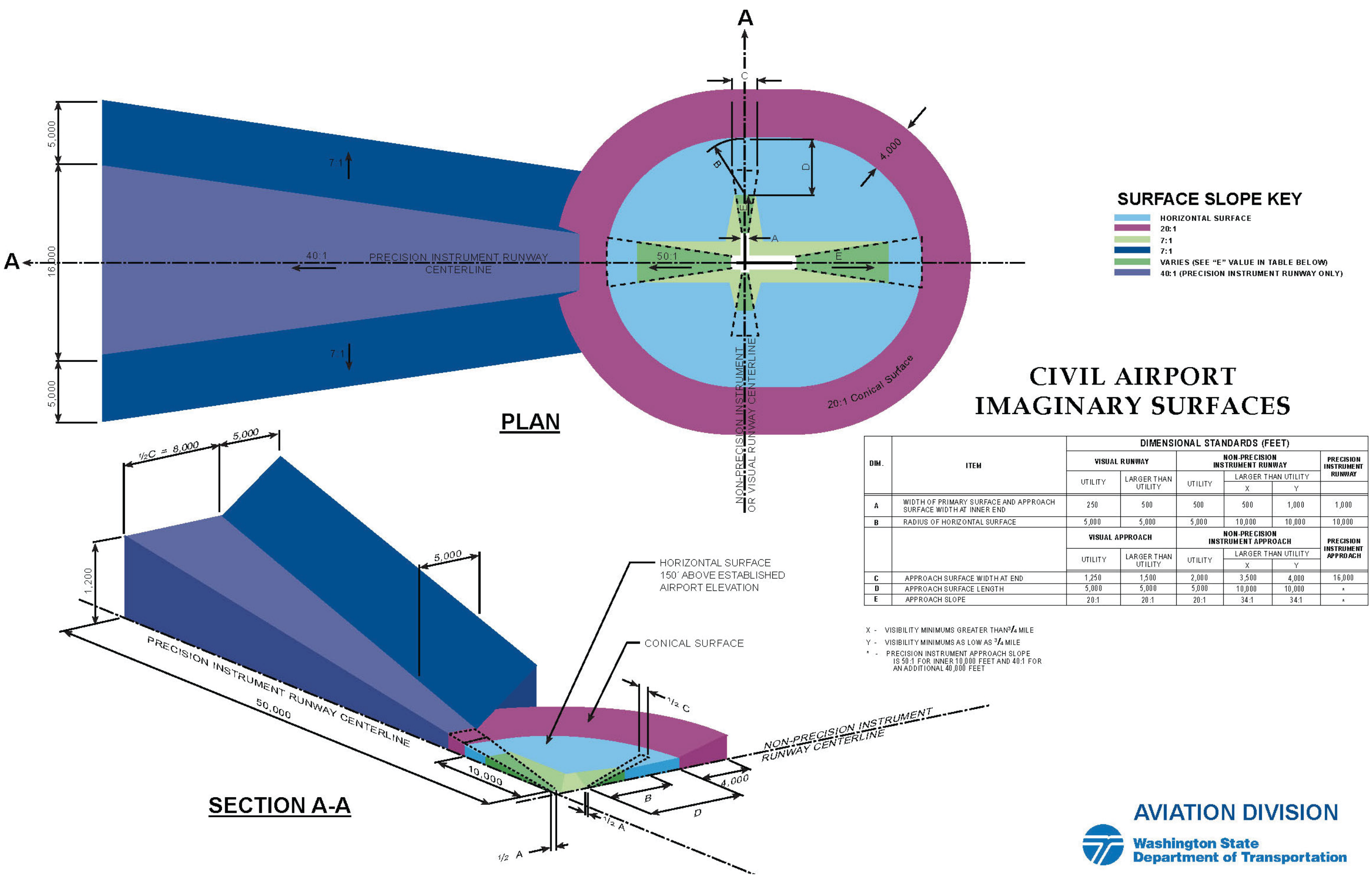
Obstruction height zones are used to limit and regulate the height of objects that could otherwise cause a loss of navigable airspace, particularly within the vicinity of an airport in accordance with 14 CFR Part 77. This regulation (abbreviated as FAR Part 77) establishes standards and notification requirements for objects affecting navigable airspace. The regulations define a set of imaginary surfaces in the airspace around an airport. Any object (including structures, trees, movable objects, and even the ground itself) that penetrates one of the airspace surfaces is considered an obstruction. Wind turbines and power plant stack towers are examples of energy technologies that would require evaluation under FAR Part 77 whereas solar panels often are not tall enough to impinge into airspace. There are other parts of the airport design AC that also affect location of structures as obstructions on airport property including proximity to NAVAIDs (and potential for interference) and potential effect on air traffic control visibility.

Part 77 functions chiefly as a device for notifying the FAA about proposed construction near an airport so that the agency can assess whether the object would be a hazard to flight. Project proponents provide notification to the FAA using FAA Form 7460-1, Notice of Proposed Construction or Alteration. Receipt of the notice enables the FAA to evaluate the effect of the proposed object on air navigation and chart the object or take other appropriate action to ensure continued safety. The FAA evaluates height concerns for land uses within the following five surface area classifications: (1) approach, (2) transitional, (3) horizontal, (4) conical, and (5) departure. Part 77 specifies height and slope restrictions based on the surface area type. A graphical illustration of the Part 77 surfaces surrounding airport runways is provided in Figure 4-2. Additionally, any proposed object with a height of more than 200 feet requires notification, regardless of proximity to an airport.

The U.S. Standard for Terminal Instrument Procedures (TERPS) defines another set of airspace protection surfaces for airports that utilize standard instrument procedures. The FAA uses these surfaces to design instrument procedures. In most cases, TERPS surfaces are higher than those of FAR Part 77 and less restrictive on the heights of objects. The FAA publishes (and regularly updates) charts showing the approved instrument approach and departure procedures for individual airports. These charts define where aircraft must fly to remain clear of obstructions near the airport. Any new object that penetrates one of the surfaces would require a modification to the procedure.

While research for this guidebook suggests that the standards of review may be inconsistent between physical and non-physical impacts to airspace, it is important to note that the FAA has a rigorous process, which involves several lines-of-business with technical expertise for considering potential hazards. Table 4-2 provides a listing of FAA divisions and their corresponding evaluation responsibilities.

Most renewable energy projects proposed on airport property will require a formal review by the FAA's OE/AAA Division. Any solar project located on airport property must conduct a glare analysis consistent with the Interim Solar Policy (*71*) and file the results with the FAA through the OE/AAA website (*72*). Wind turbines located adjacent to existing structures will likely rise up to the imaginary surface thresholds. Geothermal and fuel cell projects are unlikely to penetrate airspace, but cranes and drilling equipment required during delivery and construction may result in a temporary impact which is subject to FAA notification.



Source: Washington State Department of Transportation, Aviation Division

Figure 4-2. Civil airport FAR Part 77 imaginary surfaces.

Filing with a Form 7460 is relatively simple. It can be done by accessing the OE/AAA website and inserting information on the location of the activity, height of structures, and attaching any supplemental documentation such as site plans and glare analysis that would facilitate the FAA's review of potential airspace impacts. The FAA regulations require that applications be submitted a minimum of 45 days prior to construction and up to 90 days is more likely for receiving a determination.

Table 4-2. FAA divisions and evaluation responsibility for aeronautical studies.

Office	Evaluation Responsibility
Air Traffic Obstruction Evaluation Office (ATOES)	FAR Part 77 requirements
Air Traffic Operation Service Group (ATOSG)	Coordination with air traffic control to identify any operation impacts
Technical Operations (Tech Ops)	Impact of NAVAIDs, electromagnetic and line-of-sight shadow interferences
Flight Standards (FS)	Review of proposals to determine the safety of aeronautical operations
Flight Procedures (FP)	Review of proposals to determine impacts on instrument procedures
Airports (ARP)	Identify impacts on different airport operations characteristics.

4.4.4 Connection to Electrical Grid

The local utility that owns and operates the power and fuel infrastructure in the project area has required procedures for project proponents working near and interconnecting to the regional network. These include standard procedures such as notification to DigSafe for any excavation related activities. The most relevant application for renewable energy projects is interconnecting the project to the electrical grid.

Because the airport must be connected both to the proposed electricity generation project to utilize the power when generating and to the grid to receive power from off-site when the renewable energy facility is not producing, it is necessary for the proposed facility and its associated equipment to be grid-compatible and accessible to the utility company.

The airport will want to contact the utility company during planning stages to discuss the proposed site and make sure that there are no unforeseen issues with physically connecting the project to the grid at that location. Once the project site and required facilities are confirmed, the airport can review the interconnection process that includes a formal site plan review to approve the interconnection concept followed by a facilities plan review to engineer the associated interconnection facilities, cost and schedule. Where the proposed project is interconnecting to a single building meter, required facilities may be limited to sub-metering and shut-off switch to allow the utility the capability of disconnecting or shutting down the system in the event of maintenance activities or even a fire in the building. For utility-scale projects that connect to a substation or at another point into the electrical grid, additional facilities may be required to convert the power to a different form for transmission on the larger grid. These facilities are typically paid for by the developer but owned and managed by the utility.

Meetings between the airport's facilities team and the utility will help move along the analysis and approval process.

4.4.5 Other Relevant Permits

Other permits may be required from local, state, and federal agencies depending on the affected resources and extent of impact. Most of these permits will be identified as part of the NEPA review. Some states, such as New York and California, also administer a state-level NEPA process which the project may also be subject to. Issues associated with other federal agencies such as endangered species will be addressed under the NEPA determination. Individual state permits for contaminated sites or water quality may be triggered and applications filed. Local permitting could include zoning and wetlands impacts.

4.5 Project Management

Effective project management requires that one internal staff person be responsible for overseeing and directing all of the various activities associated with planning and implementing a particular project. Project management skills are not specific to renewable energy projects; however, there will be some parties that require involvement and therefore coordination and communication. The project manager will oversee each of the processes described earlier.

Effective project management includes identifying team members, communicating their responsibilities, providing a schedule for completion of interim milestones, and communicating regularly with the team to ensure that the project is meeting expectations. Designating team leaders for individual tasks can help build the team structure and spread out responsibility. Task leaders might include planning, permitting, financing, procurement, and operations and maintenance. Regular meetings with the team are useful for tracking progress and identifying challenges early when they can be effectively managed.

Team leaders can then coordinate as appropriate with non-airport team members. For example, the planning team leader may be the appropriate lead contact with the FAA to ensure early and often coordination. The facilities team leader will likely already have a relationship with the utility and can speak their language.

4.6 Successful Implementation

Over the past 8 years, airports have successfully implemented renewable energy projects. One of the important benefits of this guidebook is that it communicates the experience of those projects to other airport readers who can apply the process and lessons learned to identifying and implementing their own projects. The case summaries presented in the next chapter discuss the various concepts described for projects that have been implemented and are now operational.

CHAPTER 5

Case Summaries

Renewable energy projects at airports have received a wide amount of exposure in the public. When projects are announced, a press release is often sent out to various traditional and internet media sources to broadly advertise the project and its benefits. Another press release is issued when the ribbon cutting occurs and much of the same information related to expected benefits is communicated. There will be occasional reports at industry conferences about results but presentations often restate much of the project's messaging. Airport managers hear about the generalities of these projects but are left to conclude that they are unlikely to be economical at their airport.

This chapter provides 21 case summaries of renewable energy projects that have been developed at airports over the past 5 years. The case summaries cover a variety of different renewable energy technologies developed at airports of differing sizes and geographies under different business structures and funding plans. Table 5-1 lists the case summaries presented.

Each case study addresses a renewable energy technology and an ownership model. The technologies and ownership structures represented are shown in Table 5-2.

The information in the case summaries provides real world information for the concepts addressed in the previous chapters. It includes a variety of project types including projects owned by airports with funding by FAA and other sources; projects owned by third party developers where the airport is a landlord and receives a lease payment; and other cases where the airport purchases the electricity and acquires the environmental attributes. It discusses the role of municipal utilities. It describes the drivers behind individual projects. It includes lessons learned that share both good experiences that may be replicated and steps that should be reconsidered in the future.

5.1 Barnstable (HYA)—Solar PV

Fast Facts

- Commissioned in 2015
- Owned by private party
- Electricity purchased by CVEC for Airport and Town of Barnstable

Project Scope

The Barnstable Municipal Airport (HYA) hosts a 5.7 MW PV ground mounted system on approximately 22 acres of land at two separate site locations north of the airport runways (see

Aerial view of ground-mounted solar project at Barnstable Municipal Airport; John Faltings, G&S Solar.

Table 5-1. Renewable energy case summaries.

	Airport	State/Country	Renewable Energy Technology	Ownership
1	Barnstable (HYA)	MA	Solar PV	Third Party
2	Boston – Logan (BOS)	MA	Solar PV	Third Party
3	Boston – Logan (BOS)	MA	Wind	Airport
4	Brainerd Lakes (BRD)	MN	Solar Thermal	Airport
5	Burlington (BTV)	VT	Wind	Tenant
6	Chicago-Rockford (RFD)	IL	Solar PV	Third Party
7	Denver (DEN)	CO	Solar PV	Third Party
8	East Midlands (EMA)	United Kingdom	Wind	Airport
9	Grant County (JDA)	OR	Biomass	Airport
10	Indianapolis (IND)	IN	Solar PV	Third Party
11	Juneau (JNU)	AK	Geothermal	Airport
12	Lakeland (LAL)	FL	Solar PV	Third Party
13	Nantucket (ACK)	MA	Geothermal	Airport
14	Outagamie (ATW)	WI	Solar PV, Thermal, Geothermal	Airport
15	Portland (PWM)	ME	Geothermal	Airport
16	Redding (RDD)	CA	Solar PV	Airport
17	San Diego (SAN)	CA	Solar PV	Tenant
18	San Diego (SAN)	CA	Solar PV	Third Party
19	Toronto – Pearson (YYZ)	Canada	Solar Thermal	Airport
20	Tucson (TUS)	AZ	Solar PV	Airport
21	University Park (UNV)	PA	Geothermal	Airport

Table 5-2. Technologies and ownership models represented in case summaries.

Type	Symbol
Renewable Energy Technology	
Solar (PV and Thermal)	
Wind (Utility-scale and Built-environment)	
Geothermal Heat Pump	
Biomass	
Ownership	
Airport	
Third-Party	

Figure 5-1). A third site with a 0.93 MW array is on four acres of land owned by the Barnstable Fire District but is managed by the airport as part of the airfield. The airport project is expected to generate 6,830,790 kWh per year of electricity, which is equivalent to power approximately 648 homes annually in the Cape Cod region. The project was installed in 2015 and is owned and operated by a private solar developer, G&S Solar. The Cape and Vineyard Electric Cooperative (CVEC) purchases the electricity through a 20-year power purchase agreement on behalf of its members, the 18 municipalities of Cape Cod and Martha's Vineyard as well as Barnstable and Duke's Counties.

Decision-Making Process

The airport was evaluating potential opportunities to expand its revenue base from non-traditional sources such as concessions, parking, airline fees, etc. The Massachusetts

Figure 5-1. HYA leased land that was not accessible for future aeronautical uses.

Solar Renewable Energy Certificate (SREC) program provided incentives for the development of large-scale solar PV projects in the state. CVEC played a unique role as it can develop and purchase renewable energy for municipalities on Cape Cod and the Islands, aggregating the electricity buyer that private developers need to finance their projects. The project required the strong coordination of CVEC to execute agreements among all the parties and to facilitate project permitting. Among a variety of permitting requirements, the airport had to file a formal release of aeronautical land for non-aeronautical purposes with the FAA, which was posted in the *Federal Register* for public comment before the project could be approved.

Financials

Electricity generated by the facility is purchased by CVEC for a flat, fixed price of $0.0725/kWh over the 20 year contract term. The value of the land lease with G&S is incorporated into the price of electricity paid by the airport. The airport and the Town of Barnstable will benefit from the state incentivized Net Metering Credits delivered in exchange for the renewable electricity, which will dynamically lower airport and town electrical costs. By hosting the solar project through the PPA and by benefitting from the associated Net Metering Credits, the project is expected to reduce the airport's electricity cost by 17% annually and provide approximately $5 million in revenue over the next 20 years. In addition to the revenue, the airport is expected to save approximately $119,197 in electricity costs during the first year. The project is also expected to provide benefits to G&S Solar from financial incentives offered by federal tax credits and Massachusetts renewable energy incentives.

Lessons Learned

The project was delayed by FAA through the 7460 review process due to concern about glint and glare experienced at other airport solar projects. Glare studies were undertaken with resulting adjustments to the solar arrays, resolving those issues, and the project received a no hazard determination from FAA.

> Customer demand for renewable energy on Cape Cod enabled the CVEC to execute a long-term contract for power which financed the solar project.

5.2 Boston (BOS)—Solar PV

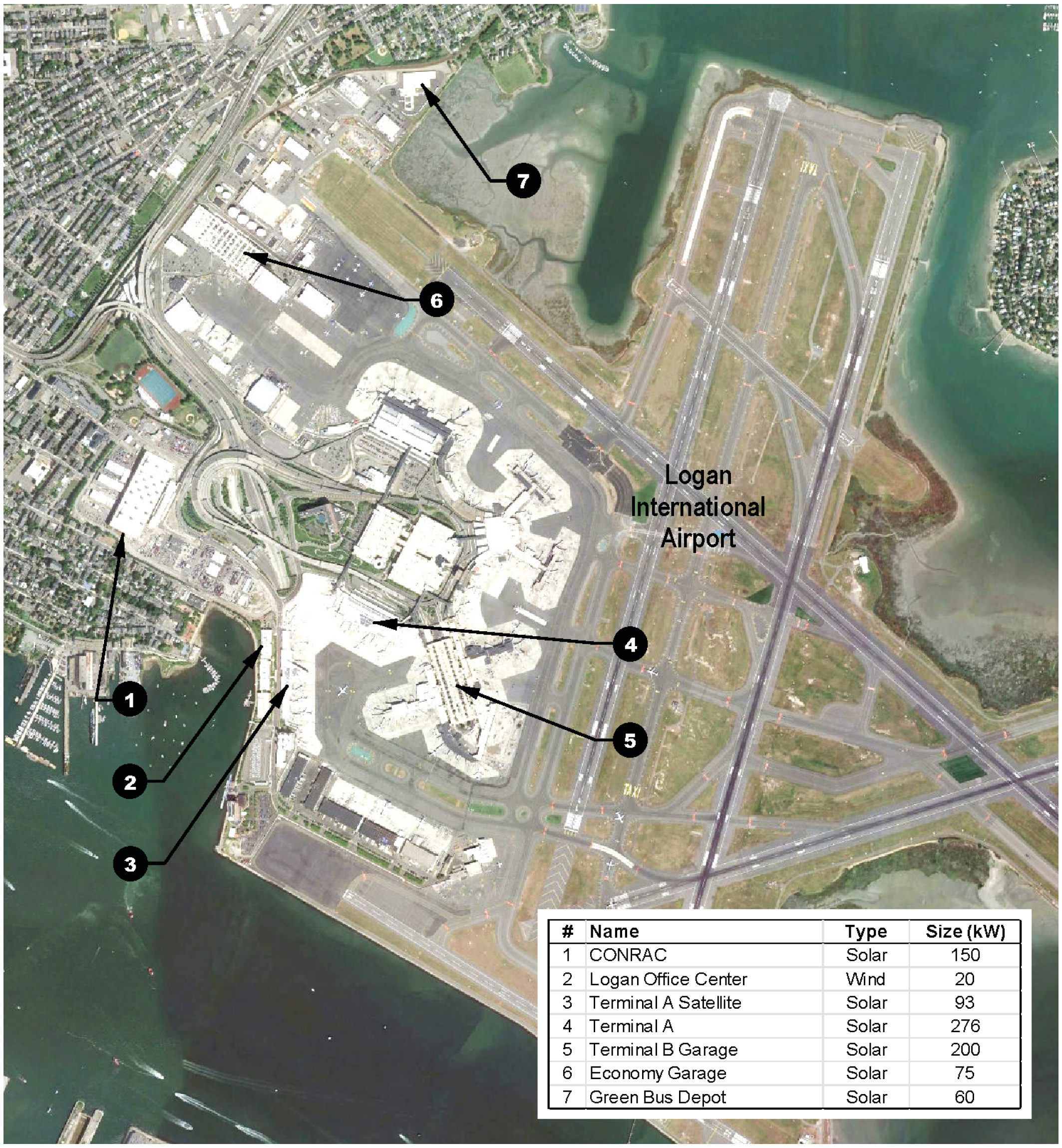
Fast Facts

- Commissioned in 2012
- Installed on first LEED terminal in the U.S.
- Owned by private party

Project Scope

Solar panels mounted on the roof of Terminal A at Boston Logan International Airport; Dan O'Brien, Solar Dock.

The project consists of a 367 kW solar project on two buildings: 274 kW on Terminal A and 93 kW on the Terminal A satellite (Figure 5-2). The facilities generate approximately 475,000 kWh per year with all of the electricity generated consumed in the buildings. The facility is owned by a private party and the Massachusetts Port Authority (Massport) purchases the electricity. The arrangement is governed by a PPA and site license agreement whereby Massport has agreed to purchase all of the electricity generated by the PV facility at a stated price per kWh that increases annually by a fixed percentage, and the developer agrees to deliver a minimum guaranteed amount of electricity. Under the site license, Massport granted the developer the right to locate, access and maintain a PV facility on the roofs of the two buildings for a term of 20 years, subject to certain conditions. There is no license fee payable by the developer, which is permissible under federal law, as Massport is purchasing the entire output for airport purposes. The developer holds title to the PV facility and to



#	Name	Type	Size (kW)
1	CONRAC	Solar	150
2	Logan Office Center	Wind	20
3	Terminal A Satellite	Solar	93
4	Terminal A	Solar	276
5	Terminal B Garage	Solar	200
6	Economy Garage	Solar	75
7	Green Bus Depot	Solar	60

Figure 5-2. Solar and wind projects at Logan Airport.

all tax credits and environmental attributes, including without limitation, RECs. Massport has the right to purchase the facility after the initial 6 years of operation, and each 5 years thereafter and at the end of the term for the greater of the stated termination price and fair market value.

Decision-Making Process

In 2010, the Massachusetts Department of Energy Resources (DOER) sought public building sites to support the installation of solar by private partners using incentives available from the American Recovery and Reinvestment Act (ARRA) to buy down construction costs. Massport agreed to partner with DOER and issued a RFP for a project on Terminal A that specified the minimum kilowatt hours of electricity it must generate. As the first airport terminal in the United States to be certified under the U.S. Green Building Council's LEED Program, Terminal A was a logical site for the array at Logan. Massport's goal was to obtain a predictable flow of renewable energy at a cost lower than the expected market price for electricity. Ameresco was selected to develop the project. Each party was incentivized by the ARRA grant, which made the project more economically viable.

Financials

The ARRA grant for $170,000 reduced Ameresco's cost to construct and the PPA rate it needed to make the project financially viable. Massport is able to purchase the power from the solar system at a discount.

Lessons Learned

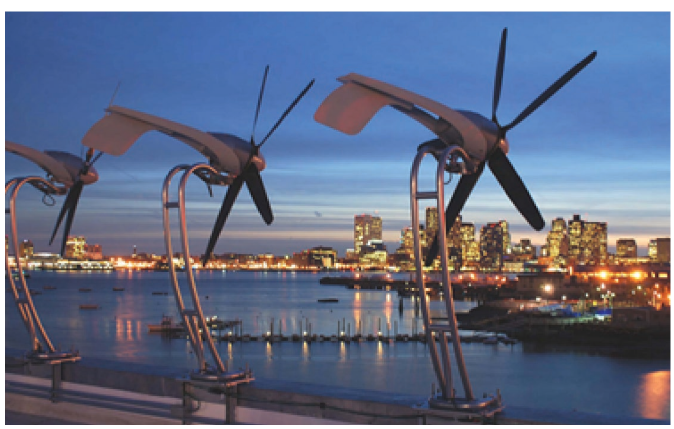
The PV facility commenced operation in 2011 and since then has provided approximately 1% of the electricity used by Terminal A at a cost per kWh that is lower than the average cost per kWh from commercial sources. Although many provisions in the agreement are standard for any PPA for a renewable energy project, other important provisions, such as those that subordinate the agreement to Massport's obligations under federal law or that incorporate Massport's standard on-airport construction requirements, were important additions to ensure that Massport would continue to comply with relevant provisions of federal aviation law while also clearly allocating the relevant risks and responsibilities between Massport, as power purchaser and owner of the buildings upon which the PV facility would be located, and the developer, as owner and operator of the PV facility.

5.3 Boston (BOS)—Wind

Fast Facts

- Commissioned in 2008
- First wind turbine generators at an airport in the United States
- Provides on-site power to administrative offices

Project Scope



Building integrated wind turbines mounted on Massport office building at Boston Logan International Airport; Massachusetts Port Authority.

Massport installed 20 roof mounted wind turbines at Logan International Airport's Office Center in July 2008. Boston Logan is the first commercial airport to generate clean energy using environmentally friendly wind turbines. Unlike the large utility-scale wind turbines that rise up 100 feet or more above the ground, making them incompatible with airports, these wind turbines attach to existing structures, which fits better with the built environment. Each turbine is 10 feet tall and has a nameplate rated capacity of 1 kW, allowing Logan to tap into the steady winds along Boston's waterfront. The wind turbines deployed utilize a unique design to allow them to capture air flow from building aerodynamics even in low-wind conditions. The project was funded by Massport, which consulted with local company Groom Energy Solutions and the turbine manufacturer Aerovironment.

Decision-Making Process

Massport is proactive in exceeding regulatory requirements to reduce the environmental impact of its operations and has developed Sustainable Design Guidelines and Standards to direct its sustainable development. It is with this philosophy that Massport evaluated the opportunity to deploy building-integrated wind turbines on the roof of its office building at Logan. Massport recognized that the proposed wind turbines were new technology and the installation would represent a demonstration of that technology. The design of the Aerovironment wind turbines also provided an architectural aesthetic to the building with visual benefits beyond its electricity generation capacity. Massport weighed the benefits and costs of the opportunity and determined the project to be on-balance a good one for demonstrating its commitment to renewable energy sources and providing data on a new technology.

Financials

Massport self-funded the project which cost about $140,000. Over a 3 year period (2011–2014), the annual output of the facility was 8,616 kWh. Massport recognized from the start that the project purpose is to demonstrate new technology and its environmental commitment, and therefore a payback analysis is not appropriate.

Lessons Learned

The turbines were forecast to generate 1,667 kWh of electricity each month or just 2% of the building's peak demand. Actual performance has been about 43% of what was predicted. However, Massport recognized in developing the project that it was deploying new technology and that the electricity generation would supplement what was provided from the grid. Its performance varies seasonally with fluctuating wind conditions. Its best production has been in the winter as demonstrated in January 2014 when the system produced double its forecasted capacity.

Overall, the project has been a success because the wind turbines have been widely recognized and are an important symbol of Massport's commitment to sustainability and renewable energy. The project has also contributed important information on the performance of building-integrated wind turbines. Massport's leadership in deploying these wind turbines was followed by several other airports, notably Minneapolis-St. Paul and Honolulu, in installing Aerovironment wind turbines on their buildings which continues to increase awareness of renewable energy among the flying public.

5.4 Brainerd Lakes (BRD)—Solar Thermal

Fast Facts

- Commissioned in 2012
- Thermal air heating system
- Funded by state and federal grants

Project Scope

Solar thermal panels located on outside hangar wall at Brainerd Lakes Regional Airport; Rural Renewable Energy Alliance (RREAL).

The Rural Renewable Energy Alliance (RREAL) approached Brainerd Lakes Regional Airport (BRD) together with the Region Five Development Commission that serves five counties in Minnesota, to assess the potential of the Airport as a site for solar thermal heating as part of a mission to promote solar energy usage in Minnesota. The assessment determined that the airport's vehicle storage building would be a good candidate for solar thermal heating to replace propane heating. The project involved an installation period of two and a half days. RREAL installed nine 4′ by 10′ solar collection panels on the side of the building, with supply ducts to distribute the heat in the building, forced by means of a 14″ fan. RREAL also installed a monitoring system and collects data to track the performance of the system output and reliability. Ongoing maintenance costs were projected to be minimal, since the system was using off the shelf HVAC components.

Decision-Making Process

RREAL coordinated development and installation of the project, and it was paid for from grants from several Minnesota organizations involved in encouraging the development of renewable energy and energy efficiency projects in the state, including RREAL, the Initiative Foundation, the Region Five Development Commission, Clean Energy Resource Teams (CERTS, associated with the University of Minnesota) and the U.S. Department of Agriculture (USDA).

Financials

The installed system cost was $23,468. The feasibility study estimated that the project would save the airport approximately 500 gallons of propane each winter for heating the vehicle storage building. With an average propane cost of $2 per gallon, the simple payback analysis for the system is 14 years with the system's useful life being 30 years. Actual savings are difficult to predict as they are correlated to the price paid in the future for propane. RREAL prepares annual reports on the performance of the system and actual cost savings. In its first (partial) year of operation, the airport saved about 208 gallons of propane from February–May 2012, about on track with

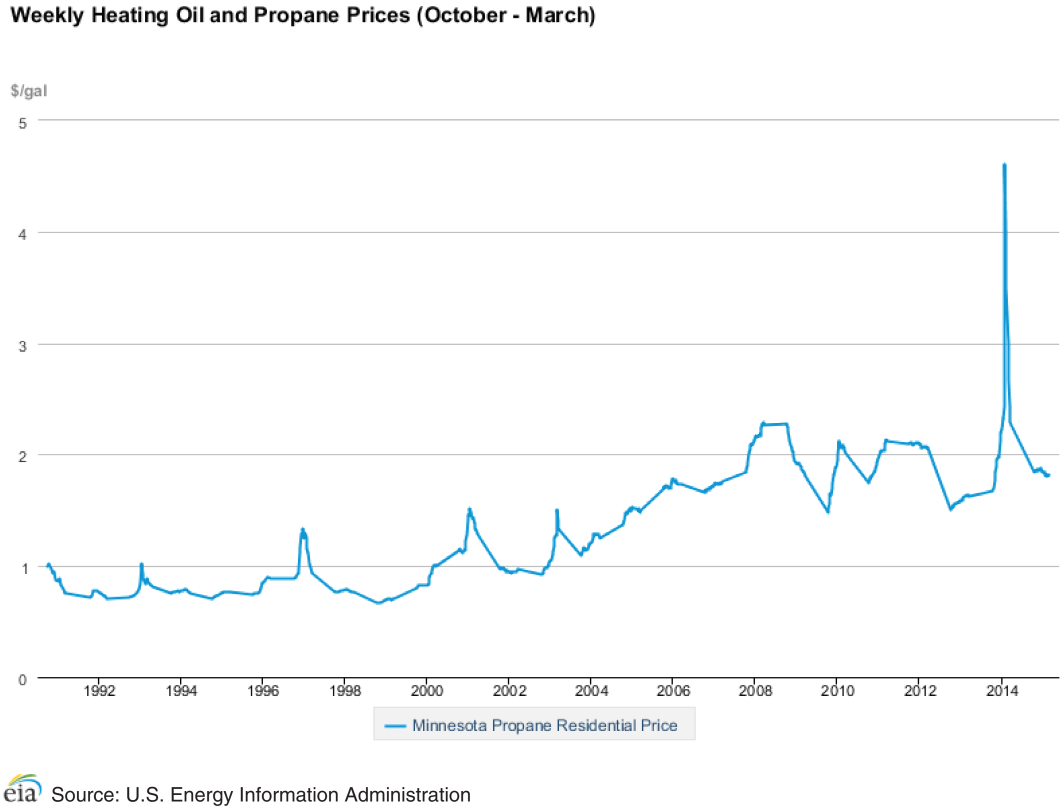


Figure 5-3. Cost of propane in Minnesota and negative financial consequences of price spikes.

expectations for the shortened heating season during which the project was online. During the winter of 2012–2013, the system saved 527.8 gallons of propane, equal to an avoided cost of propane of $1,389. In the winter of 2013–14, the avoided propane was 428 gallons and the cost savings was $1,039. As shown in Figure 5-3, price spikes can dramatically increase avoided costs and also demonstrate the price stabilization benefits that renewable energy provides in avoiding price volatility of fossil fuels.

Lessons Learned

While not initiated by the airport itself, the airport was able to construct this solar thermal project and achieve savings by accessing a variety of resources available in the State of Minnesota to fund renewable energy and energy efficiency projects. RREAL, the Region Five Development Commission, the Minnesota Department of Commerce and the other organizations communicate and coordinate regularly on renewable energy and energy efficiency projects in Minnesota, a paradigm that some other states also have in place. Airports, particularly those located in more rural areas, may be able to access state and local grants for initial planning, as well as some or all of the construction costs of smaller renewable energy and energy efficiency projects that can have a tremendous positive impact on longer term operating costs.

Solar thermal and biomass represent opportunities for airports to make their heating source renewable.

5.5 Burlington (BTV)—Wind

Fast Facts

- Commissioned in 2010
- First utility-scale wind turbine at an airport in the United States
- Owned and operated by FBO

Project Scope

Utility-scale wind turbine at Heritage Aviation, Burlington International Airport; Christopher Hill, Heritage Aviation.

Burlington International Airport (BTV) is home to the first utility-scale wind turbine at an airport in the United States. The turbine is owned and operated by Heritage Aviation, a FBO at BTV. The wind turbine is a Northwind 100, a 100kW wind turbine manufactured by Northern Power of Barre, VT. It generated approximately 175,000 kilowatt hours in 2013, which is enough electricity to power approximately 15 homes and provides approximately 15% of Heritage Aviation's electricity needs.

Decision-Making Process

Heritage Aviation sought to develop a green FBO terminal at BTV. In identifying renewable energy opportunities, it prescribed solar PV on the roof but determined that more renewable electricity could be generated through a utility-scale wind turbine. They worked with Northern Power Systems, an established local wind energy company to determine how this could be accomplished at an airport. The hangar and energy systems were constructed in 2010 and the building was certified by the U.S. Green Building Council under its LEED at the gold level. The construction and permitting of the wind turbine was the responsibility of Heritage, though the airport did cooperate, as needed, in securing FAA and power company approvals.

Financials

It is estimated that the wind turbine off-sets about $13,000 in electricity costs annually. The airport does not use any of the electricity produced nor does it receive any additional compensation or lease payments. At the end of the property lease the turbine would become an airport asset since it is considered an improvement that would revert to the airport.

Lessons Learned

This project is an example of a tenant owned renewable energy facility. The airport worked with a tenant to construct and implement green energy programs. The benefits to the airport are primarily non-financial including fostering stakeholder goodwill and improving the value of the leasehold improvements at no cost to the airport.

5.6 Chicago-Rockford (RFD)—Solar PV

Fast Facts

- Commissioned in 2010
- Project located adjacent to RPZ
- Owned by private party

Project Scope

Ground-mounted solar project near approach to Runway 1, Chicago Rockford International Airport; Brian Welker, Crawford, Murphy & Tilly.

Rockford Solar Partners (RSP) currently operates a 3.0 MW PV ground mounted project on 15-acres of land near the approach area to Runway 1 on the south side of the airport. The 3.0 MW project is Phase I of a much larger project anticipated at up to 62 MW. Phase I is expected to generate enough electricity to power up to 400 homes while the full build-out of 62 MW could generate enough electricity to power up to 6,900 homes. The project is owned by Rockford Solar Partners (RSP) which is composed of Elgin-based Wanxiang America and Chicago-based New Generation Power. Wanxiang America is a solar manufacturer and supplied panels for the initial phase of the project. The airport land is leased from the Greater Rockford Airport Authority (GRAA) by the City of Rockford who in turn leases it to RSP.

Decision-Making Process

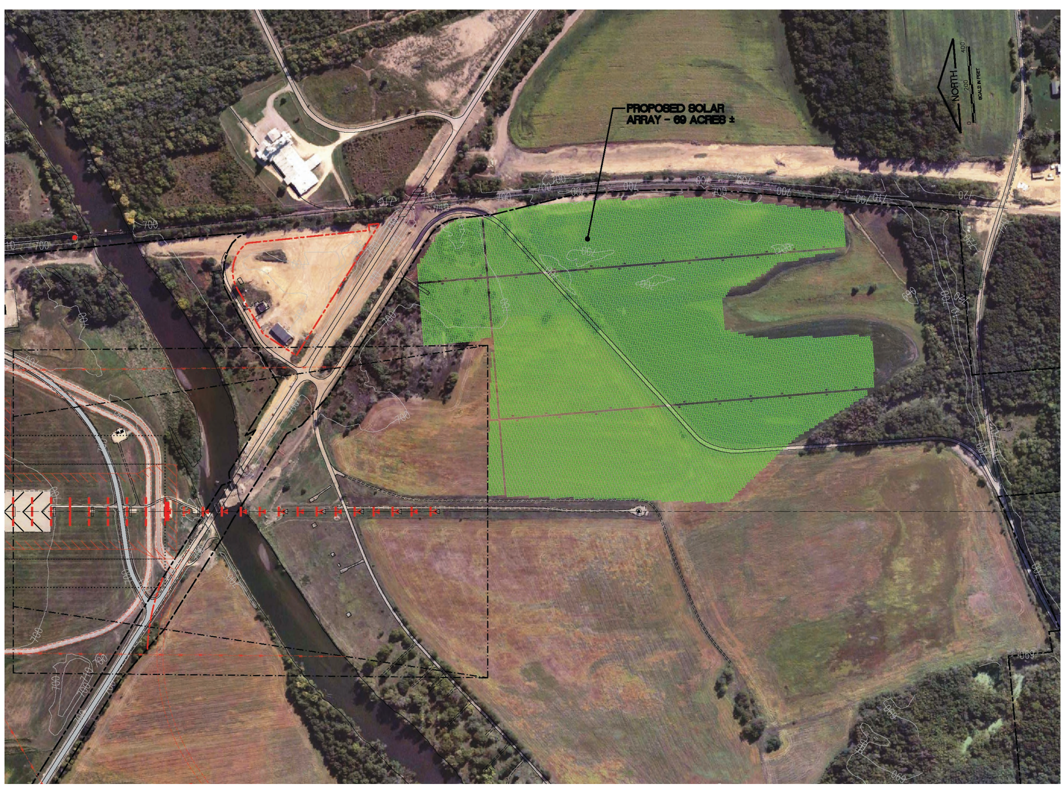
After a comprehensive siting process, Wanxiang America selected a site in the City of Rockford, IL for establishment of a solar PV manufacturing facility. RSP worked with the City of Rockford to utilize available federal grants under the ARRA for the development of a solar project to help demonstrate the benefits of solar energy and in support of the city and airport's commitment to sustainability. During the initial site selection process, the airport and city had identified an on-airport parcel located that was considered low value and not conducive for future aeronautical, industrial or commercial development, but potentially suitable for a utility-scale solar farm. In consultation with the FAA, GRAA obtained concurrent use approval for non-aviation use of the parcel. As a condition of the approval, FAA required that FMV also be derived from leasing the land to the developer.

Financials

The airport was able to establish a land lease value of $160/acre based on guidance provided in *2011 Illinois Farmland Values and Lease Trends* prepared by the Illinois Society of Professional Farm Managers and Rural Appraisers. The FAA agreed with request for a concurrent use, which allows for the use of dedicated airport property for a compatible non-aeronautical use while serving the primary purpose for which it was acquired, which was protection of the land from aeronautical obstructions. The City of Rockford leases the land from the GRAA for $11,200 a year. RSP was awarded a $4 million grant from the Illinois Department of Commerce and Economic Opportunity (DCEO) with funds originating from the U.S. Department of Energy through ARRA to decrease project cost and price of electricity generated. RSP executed a 20-year PPA with Ameren Illinois to purchase the power and the Renewable Energy Credits under the Illinois Power Agency's long-term renewable energy procurement program. The purchase helps Ameren meet its obligations under the state RPS.

Lessons Learned

Given that the 3.0 MW project is located near the approach area to Runway 1 as shown in Figure 5-4, this is an example of the necessity of early planning with FAA. The central issue that



Source: Exhibit, Brian Welker, Crawford, Murphy & Tilly

Figure 5-4. Footprint of Rockford Airport solar array relative to the RPZ and MALSR.

FAA had for this project was to ensure that glint and glare issues will not affect sensitive receptors such as the ATCT and pilots on approach, and the project will not impact navigational aids, cause communication interference or have other aeronautical impacts. Additionally, as a proposed on-airport solar facility requires federal action through the FAA, early consultation with the FAA on required NEPA approvals and process was needed.

5.7 Denver (DEN)—Solar PV

Fast Facts

- Developed four separate solar PV projects
- All third party owned, airport buys power
- Each one has produced successively cheaper electricity tracking the solar market

Project Scope

Four solar projects located at Denver International Airport.

Denver International Airport (DIA) has been at the forefront of developing on-airport solar PV facilities. It currently has four projects over 55 acres totaling 10 MW and the design generating capacity is 16.1 million kilowatt hours, enough electricity to power roughly 2,580 Denver residences. The solar facilities are each owned and operated by a private, third party who leases land from the airport. The airport purchases all power generated from each array through a PPA. Any excess power generated not used by the airport is sold to Xcel Energy, the airport's electric service provider. The RECs are sold by the third party facility owners directly to the utility, Xcel, through a long-term contract.

Decision-Making Process

Given Denver's ample acreage and the airport's strategic and sustainability goals, the airport was very interested in developing renewable energy projects such as solar power. A main financial driver was the opportunity to sell RECs to Xcel Energy under its Solar Rewards Program that provides an incremental funding stream in addition to the market price of electricity. For each project, the third party owner in cooperation with the airport responded to an Xcel RFP to purchase RECs from the project.

Financials

The project financing is structured around two contracts with the third party owner of each facility: one for the power, and one for the RECs. DIA buys the power from each array owner through a long-term power purchase agreement or PPA at a specific electricity rate as summarized in Table 5-3. The prices for each project reflect the dramatic decrease in solar energy costs between 2008 and 2014.

Xcel Energy's regulations require that arrays be placed behind an existing meter and can only offset usage at tariff rates for that meter; the excess electricity is sold through net-metering to the grid for which the airport receives a payment at the AHIC. Solar II serves the Airport's Fuel Storage and Distribution Facility; the production is closely balanced to the annual usage and thus mostly offsets energy tariff. However, most of the electricity produced by Solar I, III, and IV is in excess of usage of the associated meter and is sold to Xcel by DIA at AHIC. The amount of excess power produced combined with the unpredictability of the AHIC rate (which is calculated retrospectively) and the method for offsetting the electricity charges at the Airport's regular retail rate (which is done at 15 minute intervals in which the peak demand rate occurs) makes it difficult to accurately predict rates for comparative purposes.

Xcel purchases the RECs through a separate long-term contract with the facility owner. Under Colorado's Renewable Energy Standard (RES), investor-owned utilities (like Xcel) must procure and distribute a percentage of all electricity from renewable source with a requirement to meet a threshold of 30% by 2020. They do so either by building new renewable energy projects or purchasing RECs from third parties. For each of the Denver Airport solar projects, the third party owner submitted a proposal in cooperation with DIA to Xcel under its Solar*Rewards program. Upon selection, Xcel provided a rebate to offset the upfront construction costs and entered into a contract to purchase the RECs at the price proposed. Xcel then owns and retires the RECs to satisfy its obligations under the RES.

The airport also receives a nominal lease payment per acre for the land occupied by the solar panels ($340.21 per acre for the 12 acre Solar IV Project). Because much of the airport's financial stake is associated with the price of electricity contained in the PPA, the ground lease payment is a matter of compliance.

Furthermore, the airport also loaned the development company $4 million for Solar II at low interest rates to further minimize the cost of the electricity.

Lessons Learned

The potential lessons learned from the Denver projects are both technical and financial. From a technical perspective simpler may be better and cheaper. Solar I is a single-axis tracking system

Table 5-3. Summary of specific electricity rates.

System	Price	Year Built
I	Fixed rate of $0.06 per KW for the first 5 years increasing to $0.1075 with an annual 3% escalator thereafter through the 25 year life of the contract	2008
II	90% of Xcel Tariff or $0.037 per KW, whichever is greater	2010
III	Tariff price with a floor price of $0.036 per KW	2011
IV	Based on Xcel's annual "average hourly incremental cost" (AHIC) with a floor price of $0.017/kWh.	2014

The AHIC is determined retrospectively and is different than the customer's retail tariff rate; AHIC exhibits greater variability than tariff and in recent years it has been lower than tariff.

that allows the panels to turn towards the sun during day with the benefit of increasing electrical production. Due to the local clay soil conditions, the system required deep drilled piers that added to the system costs. Further, the tracking system has experienced hydraulic and other operational problems that impacted system production. Airport officials note that despite these problems solar industry sources have noted that newer tracking models may not experience the same issues that have affected Denver's system. With respect to finances, large electrical consumers would benefit from a change in Colorado's prohibition of virtual net metering, which would allow a multi-meter property owner to aggregate meters as opposed to associating an array behind a specific meter. In addition, basing excess power sales on the highly variable AHIC rates (which are calculated by the utility retrospectively based on the utility's actual cost for incremental purchases of electricity) makes calculating financial projections difficult at best.

> The price of electricity paid for each of Denver's four projects shows how the cost of solar PV has dropped dramatically since 2008 as the industry and the market have matured.

5.8 East Midlands (EMA)—Wind

Fast Facts

- Commissioned in March 2011
- Largest wind project at an airport in the world
- Provides 6% of terminal electricity needs

Project Scope

Utility-scale wind project at East Midlands Airport in the UK; Manchester Airports Group.

As part of East Midlands Airport's (EMA) commitment to carbon-reduction measures, the airport installed two utility-scale large wind turbines in March 2011. This is a rather unique project in that height of the turbine is approximately 150 feet tall and can potentially cause airspace and safety concerns for aircraft. The airport conducted a variety of analyses to address such issues over a 3 year period including (1) obstacle limits; (2) wake and turbulence effects; and (3) effects on airport radar and communication systems. The project was entirely funded by East Midlands Airport with no grants. The installation consists of two Wind Technik Nords (WTN 250) turbines, each with a nameplate rating of 250kW, a hub height of 30 meters above ground level and blade diameter of 30 meters. The turbines have been operating for over 3 years and the production has met or surpassed the initial estimates of electrical generation. In FY 2013, the turbines generated 563 MWh of electricity, or 6% of the airport company's electrical demand (excluding tenant electricity use) which reduced the airport's gross carbon emissions by 251 tonnes CO_2e pa (carbon dioxide equivalent).

Decision-Making Process

EMA is part of the Manchester Airports Group (MAG) and is committed to reducing carbon emissions from its ground operations through a variety of methods. Evaluating and installing renewable energy technologies at the airport is a key component toward that goal. The airport is always evaluating renewable technologies such as solar, biomass, biomass feedstock, and electric vehicles to reduce CO_2 emissions. Since the airport is located on a bluff where wind speeds are generally higher compared to locations below the bluff, wind turbines were a natural fit for the airport. The economics of the project were evaluated by the turbine size and potential generation based on estimated wind speeds, electrical usage, and costs as well as the feed in tariff (FIT) price. FIT payments are paid to generators of renewable energy by the UK Government and are based on the type and scale of the renewable technology installed. Without the FIT incentive, the project would have had a much lower ROI and the business case for the project would have been less attractive.

Financials

The cost of the project was £1.2 million (British), which is approximately equivalent to $1.97 million (U.S.). The estimated annual rate of return of the project is 11%.

Lessons Learned

The project has been a success, with minimal objections from surrounding communities and the airport is pleasantly surprised with the results so much so that East Midlands is evaluating two additional wind turbines in the future. The airport has also developed an education area called the Aerozone where students can learn more about the wind turbines, renewable energy and other projects currently employed by the airport to reduce carbon emissions. The Aerozone has been very successful and receives up to 5,000 visitors per year.

5.9 Grant County (JDA)—Biomass

Fast Facts

- Commissioned in September 2010
- Part of LEED certified terminal
- Heats half of the terminal's needs

Project Scope

Feedstock storage bin for biomass facility at Grant County Regional Airport; Patrick Bentz, Grant County Regional Airport.

JDA built, in conjunction with and support from the U.S. Forest Service, a new airport terminal building equipped with a biomass boiler. Biomass was included as part of the building's green design, which meets the requirements of the U.S. Green Building Council's LEED Program's silver certification level. The biomass system burns wood pellets provided by a local mill and provides about 50% of the building's heating load.

Financials

The added cost for installing the biomass boiler over a convention boiler was $225,000. The annual cost for wood pellet fuel is $3,500. Annual operations and maintenance costs for the system are $500. Subtracting those costs out, the annual savings for the system is $7,520. The project would pay for itself in 30 years, assuming the savings remain constant.

Decision-Making Process

Prior to 2010, Grant County Airport administered the airport from a residential home on the site built in the 1940's. The airport is an important staging point for the USDA forest fire fighting activities that had been run out of several modular buildings. The USDA decided to help the airport construct a new building and it executed a 15-year lease with the county as part of its commitment. However, one of the USDA's design requirements was that the building be designed to meet LEED silver certification. Biomass was a logical design component given the close proximity of a wood pellet mill for both cost effectiveness and local economic development purposes. The county and USDA pitched the project to a number of state and federal agencies including the Oregon Department of Transportation and the FAA which provided the bulk of the funding for the terminal building. The USDA provided funding for the building as well, but also issued a grant for the biomass project under its Rural Development Grant Program.

Lessons Learned

While the economics of this project example are not particularly strong, it offers a model that may be repeatable that would show stronger financial benefit. Because the system was sized to support only half of the building's heating capacity, the amount of savings was limited. Were a full system built, payback would have been a more manageable 15 years. In addition, local electricity costs in Oregon are relatively low and therefore savings of biomass heat compared to electricity will be lower per kilowatt hour than in other regions of the country with higher heating costs.

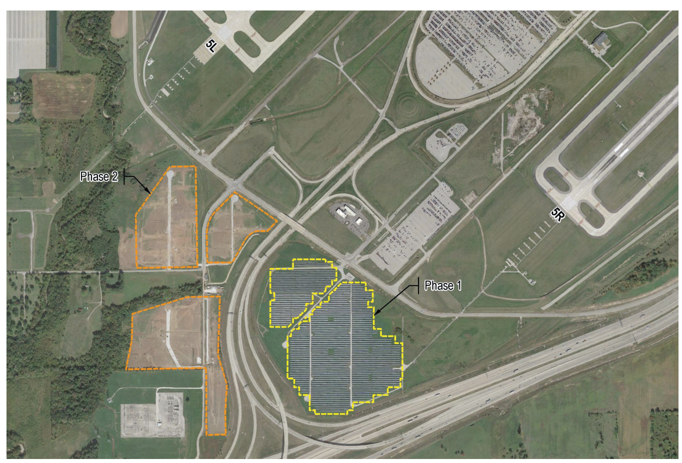
> Biomass could be a cost-effective alternative to oil, gas, or propane for small airports looking to upgrade their heating system.

5.10 Indianapolis International Airport (IND)—Solar PV

Fast Facts

- Phase I commissioned October 2013; Phase II commissioned in December 2014
- Airport leases the land to a third party
- Power and RECs sold to the utility

Project Scope



Aerial view of Phase I and II of the ground-mounted solar project at Indianapolis International Airport.

The solar farm at the IND is the largest on any airport in the world. The project covers 162 acres of airport land and has a nameplate capacity of 22 MW. It produces 31.7 million kWh of electricity annually—enough to power 3,210 homes. The facility was constructed and is owned and operated by a third party private entity that holds a long-term land lease with the airport. The electricity generated by the solar farm is fed into the electric grid and the Indianapolis Power & Light (IP&L) purchases the power and renewable energy credits. The project was implemented in two phases with the first phase using a fixed panel system commissioned in October 2013, and the second phase with single axis tracking system commissioned in December 2014.

Decision-Making Process

The IP&L solicited bids to purchase renewable energy from projects generated in its service territory. The Indianapolis Airport Authority (IAA) was approached by private developers to host such a facility in support of a bid to IP&L. The IAA had a considerable amount of land that was not being used for aviation purposes that could generate lease revenue, create construction and permanent jobs, and put some of the property tax-exempt land owned by the airport back on the tax rolls with property taxes being paid by the project's private owner.

The IAA initiated an RFP process in July 2011, offering to lease land for 30 years at the airport for solar development as a way to generate revenues without assuming any of the risks of owning the project, while further enhancing the airport's reputation for environmental awareness. The project was awarded to a local development group co-headed by Telamon and Johnson Melloh Solutions which later teamed with a large Taiwanese solar panel manufacturing company's U.S. subsidiary, GES USA, to provide the panels and own the project. Following award, the developers needed to seek approval for the project from the Indiana Utility Regulatory Commission (IURC) and negotiate a 15 year PPA with IP&L.

Financials

The IAA acts as a landlord for the facility and receives an annual lease payment of approximately $250,000 for the term of the land lease. It was also necessary for the developers to obtain a PPA from the IP&L, which provides the long-term revenue stream to support project financing.

Lessons Learned

The most important lessons learned from the solar project development relate to appropriate risk sharing between the public and private sectors, and the awareness that public officials must have of the complicated network of participants involved in the development, regulatory approval, design, and construction process for a renewable energy project. In this case, the IAA made a decision prior to issuing the RFP that its most advantageous role was to act as landlord and facilitate the process, but not share in any of the financial risks of the project. This enabled the IAA to focus on making sure that its basic mission—running an airport—was not going to be impaired by the location of the solar project on its land and the construction process, leaving the IAA more in the role of monitor and reviewer, rather than active participant, in the development issues. In addition, it did not provide any financial guarantees for the project, or agree to purchase any of the power, so its financial risk was limited to revenues foregone if the project was never completed.

The other important factor leading to the success of this project was that the IAA actively cooperated with the developers during the development process as issues arose. The developer needed to go back to the IURC and IP&L multiple times to negotiate and receive regulatory approval for changes to the initial contracts; without these changes, it would have been impossible for the project to be financed. For example, the initial term of the IP&L power purchase agreement need to be extended from 10 to 15 years in order to make the project economics work. By maintaining flexibility and patience, the IAA enables developers to successfully complete their required approvals and negotiations, and proceed with construction.

5.11 Juneau (JNU)—Geothermal Heat Pump

Fast Facts

- Commissioned in May 2011
- Supplies heating/cooling to terminal and heats walkway at terminal entrance
- Cost savings estimated at $125,000 annually

Project Scope

Installation of ground loop components of geothermal system at Juneau International Airport; City of Juneau.

The City of Juneau constructed a geothermal heating and cooling system as part of a major terminal renovation and expansion project. The system consists of 108 vertical borings 350 feet deep and 31 electric heat pumps. A liquid comprised of 88% water and 12% methane circulates through the closed loop system of HDPE piping that is 16 miles in length. The system not only provides heating and cooling to the terminal building but also runs under the sidewalk at the front of the terminal keeping it free of snow and ice.

Decision-Making Process

The airport was interested in options for designing and constructing a modern terminal. It allocated $40,000 to study the development of the ground source heat pump system. The feasibility study concluded that a ground source heat pump system would have a lower life cycle cost than a traditional HVAC system. Since funds could only be obtained to support construction of a portion of the entire building's heating and cooling system, half of the building is powered by diesel boilers until it can be replaced with a new system. Given the lack of regional experience with geothermal construction, it was decided to bid the wellfield part of the project separately from the building interior HVAC system. The wellfield was bid with a second project at the Dimond Aquatic Center to attract broader bidding interest which improved the economies of scale.

Financials

The City was awarded a grant of $513,000 for the project from the Alaska Energy Authority which paid for about 50% of the total geothermal project cost. The analysis of fuel costs when comparing 2008 to 2011 determined that the geothermal system saved the airport $130,519 in avoided diesel costs. The added electricity costs between 2011 and 2008 were determined to be $15,544 which also accounted for the increase in building size of 16,000 sf after renovations were completed, resulting in an annual costs savings of $114,985. It was also calculated that the avoided labor and equipment cost necessary to keep the front of the terminal free of snow was estimated to be $11,000 for a total savings of $125,985.

Lessons Learned

System performance has been difficult to measure given that the system is designed for half of the building with the other half served by traditional systems. Performance data has been reported for year 2011 as the first year the system was operational. This has been compared with calendar 2008 before the new system was installed and terminal renovation and expansion were undertaken. While heating and cooling demand from outside sources decreases with the geothermal system, electricity use actually increases due to the demand from the geothermal pumps. Therefore, the cost increases in electricity must be subtracted from the cost savings of the heating and cooling to evaluate the net change.

5.12 Lakeland Linder Field (LAL)—Solar PV

Fast Facts

- Commissioned October 2012
- Owned and operated by a third party
- Municipal electric company purchases power and credits airport electric bill

Project Scope

Aerial view of ground-mounted solar project at Lakeland Regional Airport; Brett Fay, Lakeland Linder Field.

LAL is host to one of the largest solar PV facilities at an airport in the United States and it will soon get bigger. The facility now operating has a nameplate rating of 6 MW, which generated approximately 11 million kWh in 2013, enough electricity to power 2,100 homes. It was constructed in two phases, occupying 43 acres of airport land, by a private third party, SunEdison, near the end of runway 9–27 including a portion of the RPZ (see Figure 5-5). The airport acts as a host to the facility and collects annual compensation as part of a ground lease agreement. The electricity generated by the facility is purchased through a PPA by the Lakeland Electric Company (LEC), a municipal utility, to provide the citizens of Lakeland with a renewable energy product. In March 2015, the City Commission approved Phase III of the project which will add

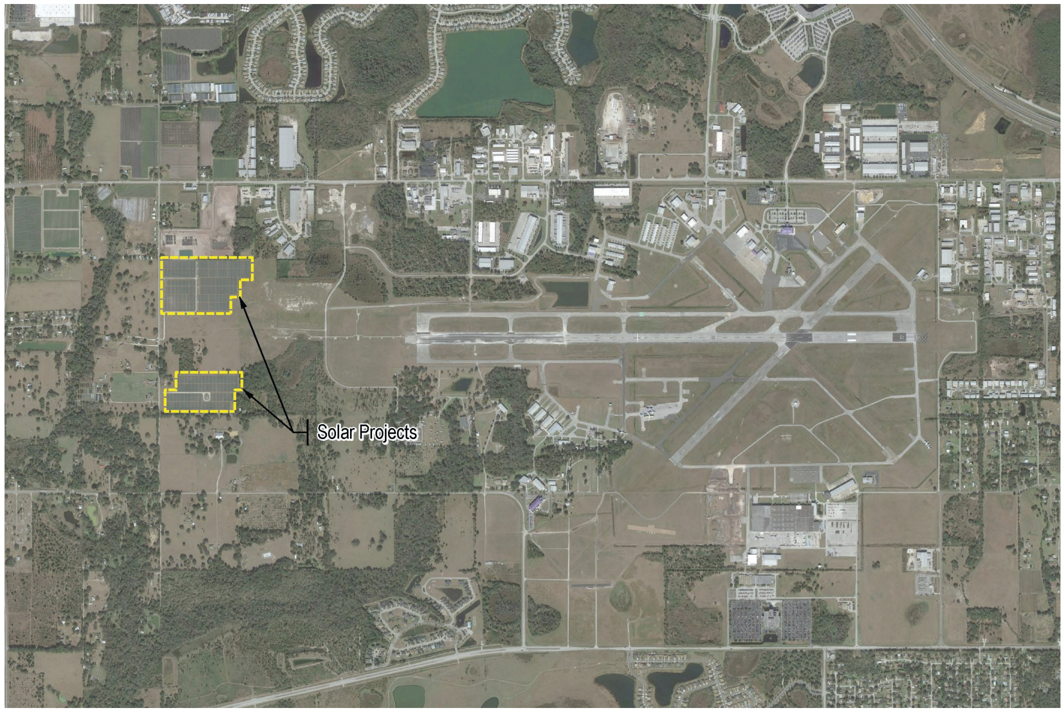


Figure 5-5. Existing solar projects at Lakeland Linder Field.

4 MW on 31 acres of land recently acquired by the airport with funding from the Florida Department of Transportation.

Decision-Making Process

The City of Lakeland determined that it would seek to have a solar facility built on town property to make an investment in renewable energy. The LEC, which already owns two fossil-fuel powered generation plants and is responsible for providing the residents of Lakeland with power, was directed to assess city property suitable to host a solar facility. LEC initially advertised an RFP to select a third party developer who would build, own, and operate facilities on city property locations to be determined in the future. Once it selected SunEdison as its private partner, the LEC contacted the airport and it identified surplus airport land that was not readily available to support aeronautical uses as a candidate site. LAL was required to ensure that the project would meet FAA leasing and airspace requirements and initiated those processes and obtained approvals. LAL and SunEdison executed a land access agreement and SunEdison constructed the facility.

Financials

The financing for the solar projects is based on LEC's commitment to buy all of the electricity generated at a predetermined price over a 25 year contract. For Phase I, price of the electricity is fixed at $0.190 per kWh annually. For Phase II, it is $0.176/kWh. For Phase III, the price dropped significantly to $0.112 / kWh which shows how much solar electricity prices have fallen as the industry has expanded over the past five years.

SunEdison, as a private company, utilizes the 30% federal ITC to meet the contracted electricity price and make a profit. The airport receives $0.02 from LEC for every kWh generated as compensation for hosting the facility. Based on 2013 generation numbers, the amount of compensation received by the airport was $218,000. LEC credits the lease value against the airport's electricity bill which has covered approximately 65% of the airport's electricity costs annually. With the addition of Phase III, the compensation will cover 100% of the energy use and the additional credits beyond that will be deposited into a fund to be used for future land acquisition.

Lessons Learned

This project is an excellent example of an airport generating revenue from renewable energy while limiting its risk. The airport hosts a solar facility but did not pay for its construction nor is it responsible for its operation. The key driver for the success of the project is the City of Lakeland's commitment to purchase the solar electricity. It is also an example of the dramatic decrease in solar PV electricity in recent years. Under the Phases I and II, the City is paying 33% more for electricity produced by solar compared to current conventional electricity. For Phase III, it is paying about an equivalent price to traditional sources. Regardless, an important economic benefit of solar is that its price is stable and known for 25 years whereas the cost of market power will fluctuate based on fuel prices. Solar provides for long-term price stability and fuel diversification.

> This example shows the level of cooperation that can occur between a municipal electric department seeking to offer a green energy product to its residents and the airport in providing sufficient land for cost effective solar energy.

5.13 Nantucket (ACK)—Geothermal Heat Pump

Fast Facts

- Commissioned in 2009
- Component of a LEED certified terminal
- Component of what is proposed to be the first carbon neutral airport in the United States

Project Scope

Terminal building at Nantucket Municipal Airport constructed with a geothermal system; Noah Karberg.

A GSHP provides chilled or heated water to air handling units, cabinet heaters, and perimeter radiation during the heating season. During the cooling season, chilled water is supplied to the air handling units only. The system is comprised of closed loop wells, ground and heat pump water circulating pumps, heat exchangers, four heat pumps, and associated dual temperature circulating pumps. The well pumps, chilled water pumps, hot water pumps, dual temperature water pumps, and GXI pumps are all variable speed.

The airport is currently working with the Massachusetts Department of Transportation Aeronautics Division on a project to maximize energy efficiency and build renewable energy to make Nantucket Airport (ACK) the first carbon neutral airport in the country. This work has resulted in a comprehensive analysis of the existing geothermal system.

Decision-Making Process

In 2009, the Town of Nantucket completed a major renovation to its airport terminal to provide additional space for passenger screening and comply with increased FAA screening requirements. The renovation was designed to meet the U.S. Green Building Council's LEED silver certification standards and included a ground source heat pump system to provide renewable thermal energy.

Financials

The geothermal project was conducted in association with a major renovation and therefore the previous heating and cooling loads are not representative of the current building. As a result, the current Terminal building was modeled using heating data to assess the amount of heating required and price. The analysis estimated that the 33,203 square foot terminal requires 278 MBTU of heating annually. Using 1 gallon = 139,600 BTU for #2 fuel oil conversion and assuming a price of $3.00/gallon, the geothermal heating avoids on the order of $6,000 in fuel oil costs per year. Given that there is an additional demand in electricity from the geothermal system to run the heat pumps, the net savings would be slightly less. However, once a solar facility is constructed, that power will be supplied by the sun.

Lessons Learned

The current analysis of the system shows that several components need to be added to optimize the system, the control interface needs to be updated to make it easier to operate, and staff needs additional training. The operation of two of the heat pumps was logged for operating hours and on/off cycles. It showed that there were short on/off cycle times, as well as 24 hour operation of the equipment. Overnight operation indicates a potential issue with the operation of the building management system. The cyclic nature of chiller operation indicates there may be control problems with the on board settings. In addition to reviewing the control set points, consideration should be given to installation of a buffer tank in the dual temperature loop, and balance valves at the individual heat pumps to properly balance the flow between them. While the equipment is generally fair to good mechanical condition, there are operating issues adversely affecting the function of the system.

5.14 Outagamie County Airport (ATW)

Fast Facts

- LEED platinum building
- Heating and cooling supplied by geothermal
- Electricity supplied by solar PV

Project Scope

In August 2013, Outagamie County Airport (ATW) completed construction of the first airport building designed to achieve a Net Zero Energy standard. The Platinum Flight Center General Aviation (GA) Terminal incorporates energy efficiency measures to reduce the amount of energy consumed in the building, and then supplies what energy is required by renewable sources. Electricity is provided by a 25 kW solar PV system on the terminal roof that will meet a majority of the facility's electricity with the remainder purchased from off-site renewable energy sources. All of the building's heating and cooling is provided by a geothermal heat pump system that is composed of 20 wells, 260 feet deep, and 10 heat pumps.

General Aviation Terminal at Outagamie County Regional Airport with a roof-mounted solar facility; Scott Volberding, Outagamie Airport.

Decision-Making Process

Airport leadership was cognizant of the volatility in the airline industry and the need to keep costs down and diversify revenue. In addition, airport budget was affected by rising energy prices. County executives established a green vision and the airport set as a goal to reduce its energy use by 70% in 2030.

In 2008, ATW undertook an airport-wide energy assessment and implemented efficiency improvements. In 2010, it constructed solar PV and solar thermal systems on the roof of the main terminal. In 2011, ATW was selected to participate in the FAA's Sustainable Master Plan Pilot Program. This unique framework for the master plan process factored in focus areas as they relate to the economic, environmental and social impact of the airport. The Sustainable Master Plan identified a comprehensive sustainable strategy for the airport. Out of this planning process, ATW identified a goal to build a net zero GA Terminal and worked with qualified professionals to design a facility that would maximize energy demand and supply required energy through renewable sources.

Financials

The solar PV system produced 32,138 kWh of electricity in 2014 which met 52% of the building's electricity demand. The avoided electricity cost from not making purchases from the electrical savings was $30,874.

Lessons Learned

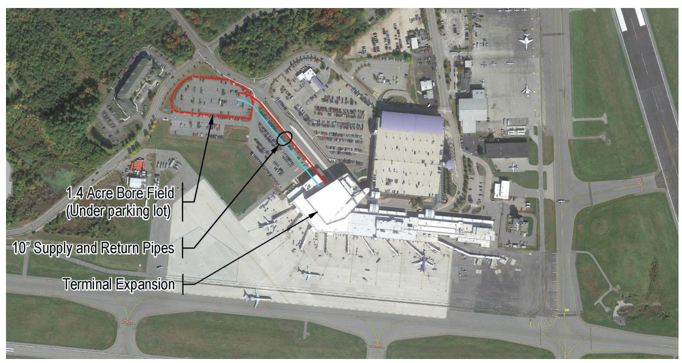
Performance of energy systems needs to be evaluated over time given response to natural conditions. There is a high-level of confidence that the building will demonstrate that upfront initial investments are paid back through reduced and predictable energy costs.

5.15 Portland (PWM)—Geothermal Heat Pump

Fast Facts

- Funding support from FAA VALE program
- Includes performance monitoring system
- Part of a LEED certified terminal

Project Scope

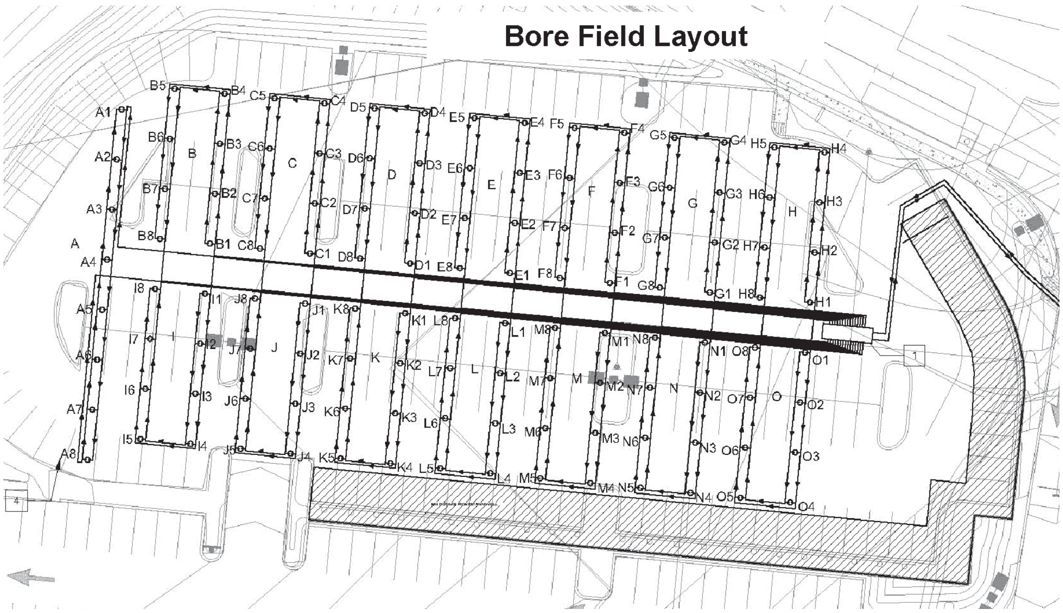


Aerial view of geothermal wellfield for Portland International Jetport's terminal expansion; City of Portland.

The City of Portland recently completed a major expansion to the existing terminal building at the Portland International Jetport (PWM). The terminal building was designed in accordance with the U.S. Green Building Council's LEED Program. An important aspect of the project is its ground source geothermal heating and cooling system which received dedicated funding under an FAA grant program designed to reduce on-site air emissions at airports. While generically referred to as geothermal, the system is actually a ground source heat pump system that uses the ground as a heat storage medium, pumping heat (stored in water) into the ground in summer and returning it to the building for heating in winter (Figure 5-6). While the geothermal system was sized primarily to serve the expanded terminal area, it has also led to the reduction in the conventional heating and cooling equipment from the pre-existing terminal. The system has been equipped with an energy monitoring/instrumentation system that is tied into the building's energy management system to quantify its actual energy and financial benefits.

Decision-Making Process

PWM and its design team identified a number of sustainable design alternatives to a conventional terminal that would help the building achieve LEED silver certification including the provision of a geothermal system. PWM developed a feasibility analysis for geothermal including how



Source: City of Portland

Figure 5-6. Bore field system consists of 120 wells, spaced 20 feet apart, each 500 feet deep, and comprised of nearly 23 miles of high density polyethylene pipe.

large a system should be built and the optimal system capacity (based on percentage of building load served). PWM allocated approximately $116,000 in at-risk testing and engineering funds to properly evaluate the viability/feasibility of a ground source geothermal system. The evaluations concluded that a smaller, more optimally sized system of 120, 500-ft deep closed loop wells would provide the best benefit to PWM. The system was not sized to handle the maximum heating and cooling demand of the terminal expansion, but was sized to handle the "base load" of the heating and cooling demand. Smaller sized (and less expensive) conventional systems were designed to handle the peak heating/cooling demands, when they occur. Based on this optimal system design, PWM estimated the project cost and evaluated the potential to fund the project through the FAA's VALE Program [based on achieving a minimum amount of Nitrous Oxide (NO_x) emissions reduction]. PWM also prepared a design for a conventional heating and cooling system in the event that the VALE grant application was not awarded. Once it was informed that the grant application was successful, PWM proceeded with final design and construction of the ground source geothermal system as part of the larger terminal expansion project.

Financials

The premium cost associated with the ground source geothermal system was $3.11 million including the pre-construction at-risk engineering costs. PWM received $2.53 million from the FAA under the VALE Program which represented 81% of the total project cost. PWM's contribution of $463,127 was funded as part of the bond for the terminal project with the annual debt service covered by revenue. The initial testing costs were also covered by available cash associated with airport revenue. Simple payback costs for geothermal system accounts for the increase in electricity usage required to run the borefield pump system and multistack heat pumps that are subtracted out of the savings from avoiding fuel purchase for a conventional heating and cooling system. The value of avoided natural gas usage is calculated on a seasonal basis using winter and summer consumption rates. The estimated net annual savings from the system is $160,000 per year which translates into a payback of the airport's total share of the project ($579,127) as 3.6 years. Without the VALE funding, the payback would have been 19.5 years.

Lessons Learned

The premium costs associated with the ground source geothermal system were relatively high and the payback period long so financial support is likely necessary if projects are to be constructed. The geothermal system has a lifespan of 40 years so the financial benefits are realized in the long-term, which PWM understood and believed the long-term investment benefits to be important. Retrofits to existing buildings, especially if their MEP infrastructure is older, can be cost prohibitive so new applications should focus on new construction or recently constructed buildings. It is also important to incorporate a performance monitoring system so that the system performance can be evaluated throughout the heating and cooling seasons, year over year. This will provide the facilities personnel who are responsible for operating the ground source system the information they need to adjust the system operation so that it can maximize both energy and financial savings. PWM continues to optimize the performance of the system as part of a broader building energy management program. Because it has a conventional heating and cooling system in the pre-existing terminal, it can use both systems to find the most efficient balance at any one time.

In studying the performance of the geothermal system, PWM has recognized that significant efficiency gains can be realized during the peak cooling months of June, July, and August by using the centrifugal chiller as the lead in cooling over the heat pumps. It is anticipated that this change could save up to $30,000 in electrical costs over the cooling season due to the greater efficiency achieved by the centrifugal chiller during these months when it is optimally loaded.

> The efficiency of the geothermal system at PWM was significantly enhanced when it installed a detailed performance monitoring system that allowed PWM staff to operate the system in accordance with changeable weather conditions.

5.16 Redding (RDD)—Solar PV

Fast Facts

- Airport owned, equipment leased
- Electricity purchased by municipal utility
- Utilized ARRA funding

Project Scope

Aerial view of ground-mounted solar project at Redding Municipal Airport; Rod Dinger, Redding Municipal Airport.

Redding Municipal Airport (RDD) in association with Halcyon Solar developed a unique solar PV project on airport property that directly supplies on average 98% of its electricity needs. The system occupies about 3 acres of land on the southwest side of the airport close to the terminal and existing electrical infrastructure. Rated at 695 kilowatts, it produces enough electricity to power approximately 100 homes. In an arrangement, RDD owns the facility but leases the equipment from a private company, which allows the airport to benefit from tax credits while also using the electricity on-site.

Decision-Making Process

Under California Law, all electric utility companies are required to purchase a portion of their power from renewable energy sources. The requirement at the end of 2013 was 20% that will increase in 2020 to 33%. To incentivize the construction of solar power in city limits and allow it to achieve state mandates, the Redding Electric Utility established a program that provides a 5 year rebate of $0.35 per kilowatt hour for approved solar projects. RDD applied for the rebate, which is funded through an energy surcharge on customers' bills. The city approved the rebate for the airport project and securing the rebate allowed RDD to proceed toward construction. RDD received required FAA approval for airspace review and other local and state permits and initiated construction.

Financials

RDD owns the facility but leases the equipment from a private company, Belvedere Equipment Finance Corporation. RDD uses rebates it receives from the Redding Electric Utility for each kilowatt hour the system generates to fulfill its lease payments to Belvedere. Once the rebate expires after 5 years, RDD can either continue to make payments to Belvedere through the 15 year term of the agreement, which is equivalent in value to discounted electricity on the open market, or opt to buy the facility after Year Seven and secure free electricity from the system more quickly after its investment is paid off. As a private tax paying company, Belvedere was able to take advantage of the ARRA grant that covered 30% of the total cost of the project equipment and pass those savings on to the airport in the form of reduced equipment lease payments.

Lessons Learned

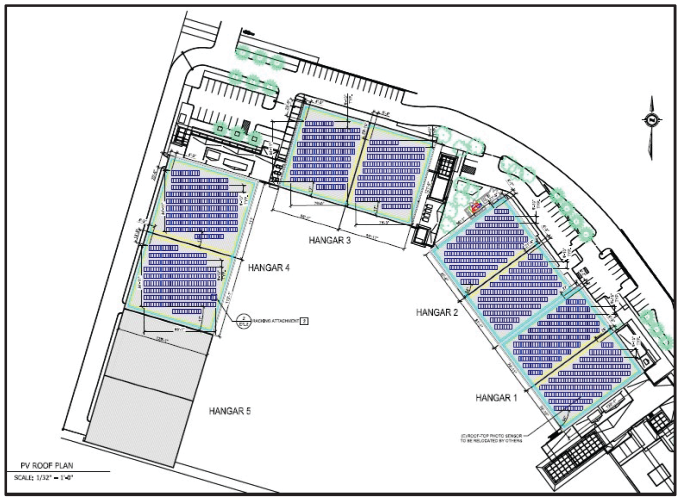
This project is unique in that the airport owns the facility but leases the equipment which allows the airport to both monetize the tax credit (by working with a private entity) and use the electricity directly on-site. An alternative arrangement would be for the airport to host the facility and execute a power purchase agreement to buy the electricity from the private owner, a structure which has been used in several other cases. The structures are similar but in the case of this project, all of the financial aspects of the project are transparent. The project also took advantage of several special circumstances including the ARRA cash grant of 30% of the project cost and the Redding Electric Utility's elevated rebate price which, at the time, was the highest in the state.

5.17 San Diego (SAN)—Solar PV

Fast Facts

- Third party owned
- Located at an FBO
- Part of LEED certified terminal

Project Scope



Engineering plans for solar proposed on new Landmark Aviation hangars at San Diego International Airport; Michael Johnson, Spear Point Energy.

Spear Point Energy is in the process of constructing a 554 kW DC photovoltaic system mounted on the roof of the new Landmark Aviation terminal/hangar building at San Diego-Lindbergh Field Airport (SAN). The solar project is part of a new LEED building constructed by Landmark Aviation as part of a 37-year lease recently awarded by SAN. Landmark Aviation is a FBO providing business aviation and aircraft charter operations at the airport. The solar project will be owned by Spear Point Energy and will consist of 1,788 modules located on the roof of the terminal/hangar building and is expected to generate approximately 1,000,000 kw-hours of electricity annually that will be sold to Landmark Aviation under a 25-year PPA. The project is designed to offset up to 80% of the building electricity needs.

Decision-Making Process

SAN awarded Landmark Aviation a 37-year lease in 2012 as part of a commitment to build a new campus facility on 12.4 acres of land at the airport. The airport required Landmark's new building meet Silver LEED certification. Landmark Aviation is committed to sustainability and reducing greenhouse gas emissions and wanted to strive higher than Silver and achieve a Platinum certification. To help attain Platinum LEED certification, Landmark Aviation looked to Spear Point Energy to develop a solar PV project to generate clean renewable energy to offset electricity usage in the building. In addition, the solar project will provide environmental benefits and reduce energy costs over a 25-year period thereby providing a cost certainty to a portion of the energy costs which helps in future planning and economic budgets.

Financials

The project does qualify for net metering in California where the utility meter is able to spin and record energy flow in both directions. Therefore, Landmark Aviation can offset some or all of its electricity usage (depending on production and electric demand) with the solar PV project through net metering. SAN does not receive any financial benefit from the arrangement with Landmark and Spear Point where Landmark is the sole beneficiary of the PPA. The airport does receive indirect benefits as an environmentally responsible landlord through the visibility of the project. The terms of the financial arrangement with Spear Point Energy and Landmark Aviation were consistent with the lease agreement with SAN.

Lessons Learned

This project is an example of a solar PV project, developed by a FBO, playing an integral role in meeting the sustainability demands by the airport for construction of a new building. One of the challenges with this project was the construction constraints associated with a small busy international airport. Available land for laydown and storage is minimal, so mobilizing and preparing for construction operations is a challenge. Also, on-field access is tightly regulated through the Department of Homeland Security, therefore, additional background checks and training were required for the construction crew, which added time and costs.

5.18 San Diego (SAN)—Solar PV

Fast Facts

- Third party owned
- Airport purchases electricity through a PPA
- Part of LEED certified terminal

Project Scope

Schematic of roof-mounted solar on Terminal 2 at San Diego International Airport; Bryan Morrison, Borrego Solar.

The San Diego County Regional Airport Authority (SDCRAA) reached an agreement with a private third party, Lindberg Field Solar 1, LLC (LFS1), whereby LFS1 will build, own, and operate solar facilities associated with Terminal 2 and the SDCRAA will purchase the power generated through a long-term contract or PPA. The project will be developed in three phases: (1) rooftop facility of 650 kW on the new wing on Terminal 2; (2) carport structures totaling 2 MW over surface parking adjacent to Terminal 2; and (3) a rooftop facility of 650 kW over the older wing of Terminal 2 once roof repairs are made. Through the purchase, SDCRAA acquires the electricity and the environmental attributes which include the RECs, emissions reductions, and carbon off-set credits. Phase I commenced construction in January 2015 with Phase II following in Spring 2015. The schedule for Phase III will be set once work is completed on the existing roof.

Decision-Making Process

The solar projects were a logical next step for the SDCRAA following the creation of a sustainability policy governing facility construction and the execution of a memorandum of understanding with the California attorney general that mandates air quality improvements as a condition for facility expansion. The recently completed GreenBuild Project includes the Terminal 2 expansion, which became the world's first commercial aviation terminal certified under the U.S. Green Building Council's LEED program at the platinum level. The solar projects will give the terminal additional LEED points. SDCRAA also recently completed a 12kv micro grid that allows it to own and manage the electrical infrastructure on airport property. It is currently planning to integrate renewable energy and energy storage into the micro grid that will allow it to "island" the airport and operate self-sustainably in the event that the grid should fail.

Financials

The price of the electricity purchased is a fixed rate of $0.1367/kWh for 20 years. The airport has the option to buy back the system after year 6 and each successive year thereafter at a pre-negotiated price. LFS1 guarantees 90% of the forecasted output and will pay an escalating rate for the difference between the guaranteed output and the actual output for supply under 90% of the forecast. Based on a conservative analysis of increasing electricity prices, the estimate of cost savings is between $4–9M over a 20 year period.

Lessons Learned

The primary lesson of the SDCRAA experience is that it was able to transform policy and legal directives into a new course and brand for the airport. It also determined that a flat PPA price was the best option for the airport so that the price of electricity remains flat. SDCRAA would also have investigated the roof of the old wing of the terminal earlier in the process as completing the rooftop phases simultaneously would have been more cost effective.

5.19 Toronto-Pearson International Airport (YYZ)—Solar Thermal

Fast Facts

- Provides pre-heated building ventilation
- Part of a LEED certified training facility
- Solar Thermal Project of the Year Award

Project Scope

Solar Thermal at Toronto Pearson International Airport's Fire and Emergency Training Institute; Greater Toronto Airport Authority.

The Greater Toronto Airport Authority (GTAA) built a new Fire and Emergency Training Institute (FESTI) in 2007 at YYZ property. The multi-functional building is composed of a school, administrative offices, safety trucks and bays, and on-site training activities. The building was the airport's first LEED silver certified building with state-of-the art technology that reduces its environmental footprint. Some of the innovative technologies incorporated into the design of the building are a green roof, recycled building materials, water saving systems and use of natural daylight. One of the more innovative and prominent technologies incorporated into the building is the SolarWall® solar air heating system, which is used to heat building ventilation air to displace heat generated by fossil fuels. Incorporating the SolarWall contributed to the LEED points needed for the silver certification.

Decision-Making Process

YYZ was the first airport to achieve ISO 14000:2004 certification for Environmental Management. Under this standard the airport has committed to:

- Ongoing commitment to pollution prevention;
- Compliance with legislation; and
- Continual environmental improvement.

As part of the continual environmental improvement, when the GTAA was looking at developing the FESTI building, it was committed to sustainable building technology and a goal of silver certification under LEED. In order to reach silver certification, the architects and engineers had to incorporate numerous efficient technologies to generate enough LEED points. One of the more innovative technologies proposed was a SolarWall system that provides heated ventilation air for the building (Figure 5-7). The technology works by the sun warming the surface of the

Source: Greater Toronto Airport Authority

Figure 5-7. FESTI SolarWall at Toronto Pearson International Airport.

perforated black collectors on the wall of the building, heats the air, and distributes the warm air through the building. During the warmer months when heating is not required, dampers open to direct the warm air away from the building thereby providing cooling efficiency during the warmer months. The advantage of the SolarWall allows for more building heat to be generated by clean solar technology thereby displacing heat generated from fossil fuels that results in fewer greenhouse gas emissions.

Financials

The SolarWall project was part of the larger construction cost of the FESTI building. The SolarWall reduces annual heating costs by $20 to $80 per square meter of the perforated black collector which correlates into annual CO_2 emissions reductions of 1 ton per 5 square meters of collector. These systems can save up to 20 to 50% of heating fuel consumption thereby leading to a relative quick return on investment.

Lessons Learned

The SolarWall system has an expected lifespan of more than 30 years with minimal maintenance cost; therefore, the financial benefits are realized in the short-term with a continuing return on investment over a long time period. Short-term benefits include displaced energy needed to provide building heat from traditional fossil fuel heating sources up to 20 to 50% of the building heat load. One other benefit of the FESTI building design was good public relations benefits from industry recognition for the variety of sustainable features in the design. Specifically, the building was featured in the *Justice Facilities Review* by the American Institute of Architects and won numerous awards including the 2007 Solar Thermal Project of the Year Award by the Canadian Solar Industries Association.

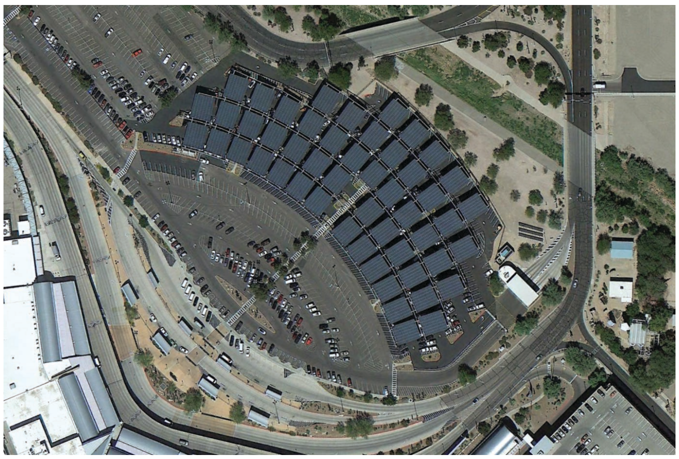
> The SolarWall technology not only provides pre-treated building air through clean renewable energy but is a unique multi-layered design that adds to the modern architectural look of the building and received numerous architectural and solar project awards which provided good public relations benefits for the GTAA.

5.20 Tucson (TUS)—Solar PV

Fast Facts

- Funding support from FAA's Section 512 Program
- Provides ancillary benefit of shaded parking
- First phase of a multi-phase project

Project Scope



Aerial view of ground-mounted solar project over main parking lot at Tucson International Airport; Fred Brinker, Tucson Airport Authority.

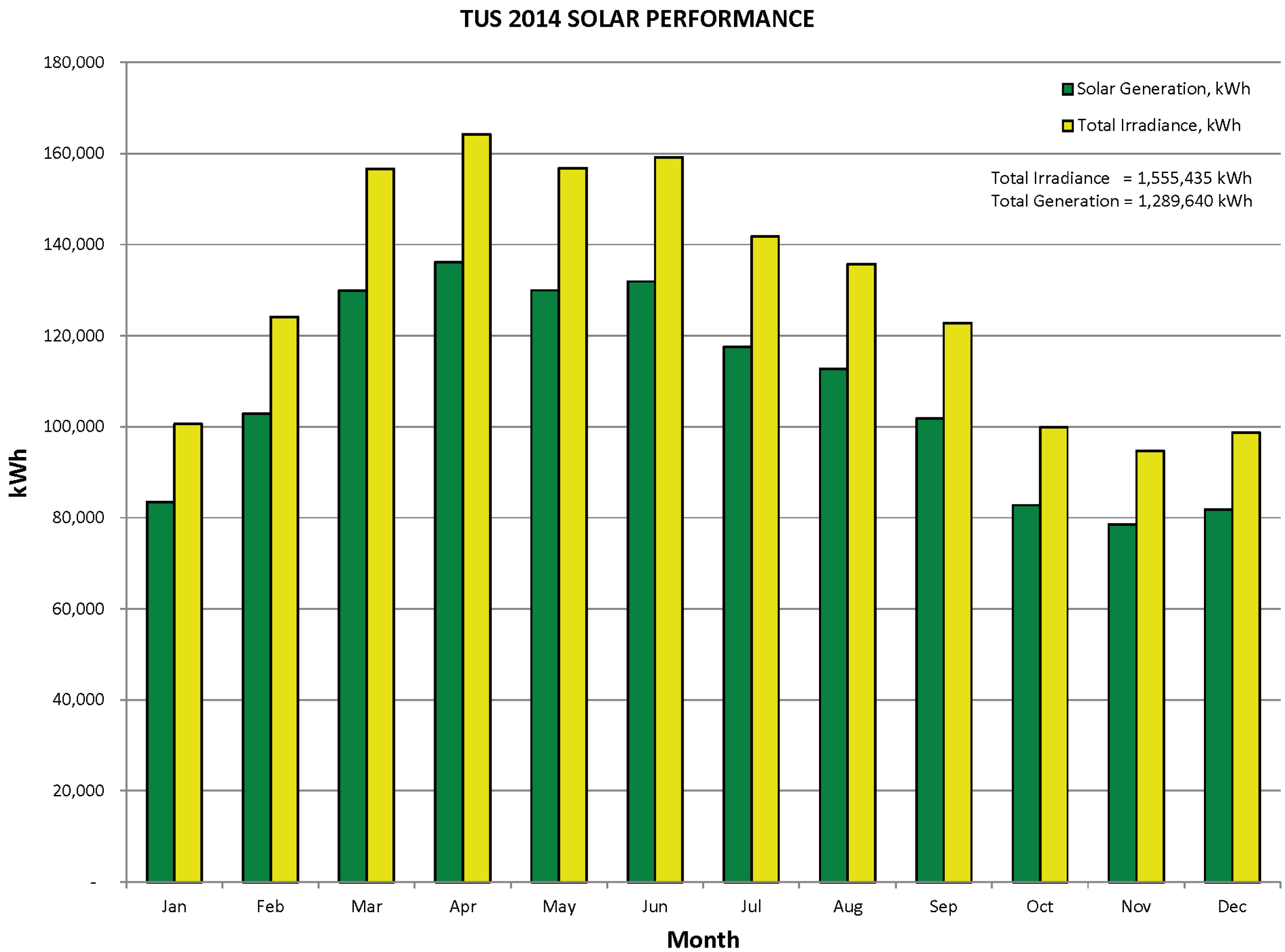
In 2013, the Tucson Airport Authority (TAA) installed a 1.0 MW PV system mounted on a canopy structure over a portion of the daily parking lot at Tucson International Airport (TUS). The project is the first phase of the airport's larger plan to construct a total of 2.5 MW of solar over terminal surface daily and hourly parking lots, providing clean energy and with the additional benefit of providing shading to visitors parking in the terminal parking lots. The 1.0 MW facility generated 1,289,640 kWh in calendar 2014 (Figure 5-8), which represents about 40% of the electricity used to heat and cool the main terminal. The project was awarded AIP discretionary funding from the FAA for approximately 91% of eligible costs of the project, which was a significant driver for the airport developing and owning the facility.

Decision-Making Process

The solar resources in Southern Arizona are very favorable to solar PV due to the abundant sunshine which has contributed to the development of a robust solar industry. The airport sought to capitalize on this market while also providing a better parking experience for visitors with shaded parking. The airport explored pursuing FAA grant money to make the project more cost effective. It was one of the first airports to utilize FAA discretionary funding for energy projects as authorized under the Section 512 "Energy Efficiency of Airport Power Sources of the FAA Modernization and Reform Act of 2012." The airport developed the project using a radial layout or amphitheater design, to follow the orientation of the parking area. The primary goal was to minimize loss of parking spaces as well as ensure the system would have an aesthetically pleasing look with a distinctive architectural design consistent with the existing buildings at the airport.

Financials

Electricity generated by the solar facility offsets electricity purchased from the grid. Total cost of the project was $6.7M, of which FAA provided funding for $5.78M, the Arizona DOT



Source: Fred Brinker, Tucson Airport Authority

Figure 5-8. Electricity produced per month by Tucson Airport Solar Array in 2014.

provided $284,000 and the TAA provided the remaining $640,000. Combining the FAA grant with funds from the Arizona DOT, the airport's share was reduced significantly improving its ROI. Payback is calculated through the reduction in electricity purchased from Tucson Electric Power (TEP). With an average electricity cost of 10.6 cents per kW-hr, the airport's return of investment for its share of the project is 5 years.

Lessons Learned

This project is an example of the new FAA funding under Section 512 to develop clean energy projects as part of the federal government's commitment to improve energy efficiency, reduce greenhouse gas emissions, and encourage/implement renewable energy projects. It demonstrates how FAA infrastructure investment in clean energy can translate into long-term savings in airport electricity budgets while also contributing to broader environmental benefits associated with climate change mitigation.

5.21 University Park (UNV)—Geothermal Heat Pump

Fast Facts

- Commissioned in October 2011
- Utilized state program that guaranteed a 15 year payback
- Example of successful terminal retrofit

Project Scope

Entrance to University Park Airport which has a geothermal system at the airport terminal; Skip Webster, The Marlin Group.

In 2011, University Park airport incorporated a geothermal heating and cooling system as part of a terminal improvement project. The project consists of four closed loops and 33 500-foot deep wells. The airport hired an energy service contractor (ESCO) through the state's guaranteed energy savings program to design the system and identify other energy efficiency measures as part of the renovation. The ESCO scoped out the project including energy efficiency upgrades and a new geothermal heating and cooling system that would be paid back over a 15 year period.

Decision-Making Process

The airport needed to replace the heating and cooling system in its terminal building originally built in 1983. It was spending a considerable amount of money keeping the old system running and the system continued to perform unfavorably. It conducted an analysis of the life cycle costs of installing a conventional heat and cooling system to that of a geothermal heat pump system. The airport was in a strong financial position to use cash to pay for the system which improved its rate of return. The state program that guaranteed energy savings provided additional assurances that the project would be cost-effective.

Financials

The airport paid for the installation of the system and other upgrades at a cost of $1.23M with available cash, and ESCO guaranteed a 15-year payback. The former heating and cooling system was fueled entirely by electricity. Electricity costs in 2010 before the system was installed were $109,000; in 2013 electricity costs were $61,000 despite the fact that the electricity rate increased from $0.0412/kWh in 2010 to $0.0620/kWh in 2013. Maintenance costs in 2010 were $67,000; in 2013 maintenance costs were $20,000.

Lessons Learned

The project is an example of a case where a heating and cooling retrofit with geothermal heat pumps can be cost-effective. The project was completed in association with other energy efficiency upgrades such as smart metering and advance controls, which make the whole building system considerably more efficient. Unfortunately, it is difficult to monitor separately the individual benefits of the GSHP and various other efficiency upgrades. However, it demonstrates the broader benefits of the whole building approach with GSHP.

Acronyms

AAIA	Airport and Airway Improvement Act of 1982
AC	Advisory Circular
ac	alternating current
ACIP	Airports Capital Improvement Program
ACRP	Airport Cooperative Research Program
ADAP	Airport Development Aid Program
ADO	Airport District Office
AHIC	average hourly incremental cost
AIP	Airport Improvement Program
ALP	Airport Layout Plan
AWEA	American Wind Energy Association
ARP	FAA Airports Division
ARRA	American Recovery and Reinvestment Act
ATCT	Air Traffic Control Tower
ATO	FAA Air Traffic Organization
AT OES	Air Traffic Obstruction Evaluation Office
AT OSG	Air Traffic Operation Service Group
BCA	benefit cost analysis
Btu-hr	British Thermal Units per hour
CATEX	categorical exclusion
CFR	Code of Federal Regulations
CO_2	carbon dioxide
COE	cost of energy
CREST	cost of renewable energy spreadsheet tool
CSP	concentrating solar power
dc	direct current
DHS	Department of Homeland Security
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOER	Massachusetts Department of Energy Resources
DSIRE	Database of State Incentives for Renewables and Efficiency
EA	Environmental Assessment
EGS	Enhanced Geothermal Systems
EIA	U.S. Energy Information Administration
EIS	Environmental Impact Statement
EMEC	European Marine Energy Centre
EPA	U.S. Environmental Protection Agency
EPC	Engineering Procurement and Construction

EP&CBT	evaluation process and cost benefit tool
ESCO	energy service contractor
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FBO	fixed-base operator
FIT	feed in tariff
FMV	fair market value
FONSI	Finding of No Significant Impacts
FS	Flight Standards
FP	Flight Procedures
GSA	General Services Administration
GSE	ground support equipment
GSHP	Ground Source Heat Pump
GTO	Department of Energy's Geothermal Technology Office
GW	gigawatts
HDPE	high-density polyethylene
HVAC	Heating Ventilation Air Conditioning
IRS	Internal Revenue Service
IRR	internal rate of return
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt hour
LCOE	levelized cost of energy
LED	light emitting diode
LEED	Leadership in Energy and Environmental Design
LOI	letter of intent
MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
MW	megawatts
MWh	megawatt hour
NAS	National Airspace System
NAVAID	Navigational Aids
NEPA	National Environmental Policy Act
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
OE/AAA	Obstruction Evaluation / Airport Airspace Analysis
O&M	operations and maintenance
PFCs	Passenger Facility Charges
PPA	power purchase agreement
PTC	production tax credit
PV	photovoltaic
PVWatts	NREL Solar Calculator
RECs	renewable energy certificates
RFP	request for proposals
RFQ	request for qualifications
ROI	return on investment
RPS	renewable energy portfolio standards
SGHAT	Solar Glare Hazard Analysis Tool
Tech Ops	Technical Operations
TERPS	Terminal Instrument Procedures
USDA	U.S. Department of Agriculture
VALE	Voluntary Airport Low Emissions

Glossary of Aviation, Energy, and Related Financial Terms

Advisory Circular: A type of publication offered by the FAA to provide guidance and recommendations for compliance with aviation regulations, policies, and programs.

Aeronautical uses: Any activity that involves, makes possible, or is required for the operation of aircraft or that contributes to or is required for the safety of such operations.

Air conditioning: Cooling and dehumidifying the air in an enclosed space by use of a refrigeration unit powered by electricity or natural gas. Note: Fans, blowers, and evaporative cooling systems (swamp coolers) not connected to a refrigeration unit are excluded.

Airport: An area of land or water that is used, or intended to be used, for the aircraft takeoff and landing. It includes any appurtenant areas used, or intended to be used, for airport buildings or other airport facilities or rights-of-way, together with all airport buildings and facilities located thereon. It also includes any heliport.

Airport Improvement Program (AIP): The AIP is authorized by the Airport and Airway Improvement Act of 1982 (AAIA) (P.L. No. 97-248, as amended). The broad objective of the AAIA is to assist in the development of a nationwide system of public use airports adequate to meet the current and projected growth of civil aviation. The AAIA provides funding for airport planning and development projects at airports included in the National Plan of Integrated Airport Systems.

Airport Layout Plan (ALP): A scale drawing of existing and proposed airport facilities, their location on an airport, and the pertinent clearance and dimensional information required to demonstrate conformance with applicable standards.

Airport Master Plan: A long-range plan for development of an airport, including descriptions of the data and alternative analyses on which the plan is based.

Airport sponsor: A public agency or tax-supported organization, such as an airport authority, city, county, state or federal government, that is authorized to own and operate an airport, to obtain property interests, to obtain funds, and to be legally, financially, and otherwise able to meet all applicable requirements of the current laws and regulations.

Alternating current (AC): An electric current that reverses its direction at regularly recurring intervals. AC occurs when charge carriers in a conductor or semiconductor periodically reverse their direction of movement. The voltage of an AC power source can be easily changed by means of a power transformer. This allows the voltage to be stepped up (increased) for transmission and distribution. High-voltage transmission is more efficient than low-voltage transmission over long distances, because the loss caused by conductor resistance decreases as the voltage increases.

Array (solar): Any number of solar photovoltaic modules or solar thermal collectors or reflectors connected together to provide electrical or thermal energy.

Azimuth: The angle between true south and the point on the horizon directly below the sun.

Backup power: Electric energy supplied by a utility or on-site generating unit to replace power and energy lost during an unscheduled equipment outage.

Balance of system (or plant): In a renewable energy system, refers to all components other than the mechanism used to harvest the resource (such as PV panels or a wind turbine). Balance-of-system costs can include design, land, site preparation, system installation, support structures, power conditioning, operation and maintenance, and storage.

Base load: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Base load capacity: The generating equipment normally operated to serve loads on an around-the-clock basis.

Base load plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Benefit cost analysis (BCA): Used by the FAA to identify proposed projects that will provide a net benefit to the aviation community. FAA requires BCAs for all capacity projects that require more than $10 million in AIP discretionary funds but can request them for less costly projects, as well.

Biomass: Organic non-fossil material of biological origin constituting a renewable energy source.

Boiler: A device for generating steam for power, processing, or heating purposes; or hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes found in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.

Boiler fuel: An energy source to produce heat that is transferred to the boiler vessel in order to generate steam or hot water. Fossil fuel is the primary energy source used to produce heat for boilers.

British thermal unit: The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

Built-environment Wind Turbine (BWT): BWTs are defined as wind turbines located in an urban or suburban environment (built environment). Most BWTs are also classified as small wind turbines, which are 100 kilowatts (kW) or less.

Capacity factor: The ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period.

Capital cost: The cost of field development and plant construction and the equipment required for industry operations.

Central chiller: Any centrally located air conditioning system that produces chilled water in order to cool air. The chilled water or cold air is then distributed throughout the building, using pipes or air ducts or both. These systems are also commonly known as “chillers,” “centrifugal chillers,” “reciprocating chillers,” or “absorption chillers.” Chillers are generally located in or just outside the building they serve. Buildings receiving district chilled water are served by chillers located at central physical plants.

Central physical plant: A plant owned by, and on the grounds of, a multi-building facility that provides district heating, district cooling, or electricity to other buildings on the same facility. To qualify as a central plant it must provide district heat, district chilled water, or electricity to at least one other building. The central physical plant may be by itself in a separate building or may be located in a building where other activities occur.

Cogeneration: The production of electrical energy and another form of useful energy (such as heat or steam) through the sequential use of energy.

Combined cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Combined heat and power (CHP) plant: A plant designed to produce both heat and electricity from a single heat source. Note: This term is being used in place of the term "cogenerator" that was used by EIA in the past. CHP better describes the facilities because some of the plants included do not produce heat and power in a sequential fashion and, as a result, do not meet the legal definition of cogeneration specified in the Public Utility Regulatory Policies Act (PURPA).

Combustion: Chemical oxidation accompanied by the generation of light and heat.

Concentrating solar power or solar thermal power system: A solar energy conversion system characterized by the optical concentration of solar rays through an arrangement of mirrors to generate a high temperature working fluid. Concentrating solar power (but not solar thermal power) may also refer to a system that focuses solar rays on a photovoltaic cell to increase conversion efficiency.

Concurrent Land Use: Land that can be used for more than one purpose at the same time. For example, portions of land needed for clear zone purposes could also be used for agriculture purposes at the same time.

Cost of capital: The rate of return a utility must offer to obtain additional funds. The cost of capital varies with the leverage ratio, the effective income tax rate, conditions in the bond and stock markets, growth rate of the utility, its dividend strategy, stability of net income, the amount of new capital required, and other factors dealing with business and financial risks. It is a composite of the cost for debt interest, preferred stock dividends, and common stockholders' earnings that provide the facilities used in supplying utility service.

Cost of debt: The interest rate paid on new increments of debt capital multiplied by 1 minus the tax rate.

Degradation rate: Quantification of power decline over time from a generating facility most often used in performance of solar photovoltaic modules.

Demand charge: That portion of the consumer's bill for electric service based on the consumer's maximum electric capacity usage and calculated based on the billing demand charges under the applicable rate schedule.

Derate factor: A decrease in the available capacity of an electric generating unit, commonly due to a system or equipment modification or environmental, operational, or reliability considerations. Causes of generator capacity deratings include high cooling water temperatures, equipment degradation, and historical performance during peak demand periods. In this context, a derate is typically temporary and due to transient conditions.

Direct current (DC): DC is the unidirectional flow or movement of electric charge carriers (which are usually electrons). The intensity of the current can vary with time, but the general direction of movement stays the same at all times. Direct current is produced by electrochemical and photovoltaic cells and batteries. In contrast, the electricity available from utility mains in most countries is AC (alternating current). Utility AC can be converted to DC by means of a power supply consisting of a transformer, a rectifier (which prevents the flow of current from reversing), and a filter (which eliminates current pulsations in the output of the rectifier).

Distributed generator: A generator that is located close to the particular load that it is intended to serve. General, but non-exclusive, characteristics of these generators include: an operating strategy that supports the served load and interconnection to a distribution or sub-transmission system (138 kV or less).

Electric generator: A facility that produces only electricity, commonly expressed in kilowatthours (kWh) or megawatthours (MWh). Electric generators include electric utilities and independent power producers.

Electric power grid: A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the state (e.g., the interconnect serving Anchorage, Fairbanks, and the Kenai Peninsula; individual islands).

Electric power plant: A station containing prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or fission energy into electric energy.

Electric system reliability: The degree to which the performance of the elements of the electrical system results in power being delivered to consumers within accepted standards and in the amount desired. Reliability encompasses two concepts, adequacy and security. Adequacy implies that there are sufficient generation and transmission resources installed and available to meet projected electrical demand plus reserves for contingencies. Security implies that the system will remain intact operationally (i.e., will have sufficient available operating capacity) even after outages or other equipment failure. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on consumer service.

Electric utility: A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities for delivery of electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and state utilities, federal electric utilities, and rural electric cooperatives. A few entities that are tariff based and corporately aligned with companies that own distribution facilities are also included.

Electricity generation: The process of producing electric energy or the amount of electric energy produced by transforming other forms of energy, commonly expressed in kilowatt hours (kWh) or megawatt hours (MWh).

Energy service provider: An energy entity that provides service to a retail or end-use customer.

Fair market value (FMV): The sale price at which a property would change hands between a willing buyer and willing seller, neither being under any compulsion to buy or sell, and both having reasonable knowledge of the relevant facts.

Federal Aviation Regulations (FAR) Part 77: Objects Affecting Navigable Airspace - Part 77 (a) establishes standards for determining obstructions in navigable airspace, (b) defines the requirements for notice to the FAA Administrator of certain proposed construction or alteration, (c) provides for aeronautical studies of obstructions to air navigation, to determine their effect on the safe and efficient use of the airspace, (d) provides for public hearings on the hazardous effect of proposed construction or alteration on air navigation, and (e) provides for establishing antenna farm areas.

Feed in Tariff: A Feed in Tariff (FIT) provides a fixed price for the purchase of electricity generated (per kWh) from a qualifying renewable resource for a given period of time. All of the electricity generated is sold to the utility at the fixed price, which is usually set above the retail price of electricity. A FIT guarantees a fixed premium rate for a given period of time, which provides a reliable revenue stream for developers to finance investments in renewable energy.

Feedstock: A raw material that can be converted to one or more products.

Fixed-base operator (FBO): Provides aviation services to the general public, including, but not limited to, the sale of fuel and oil; aircraft sales, rental, maintenance, and repair; parking and tie-down or storage of aircraft; flight training; air taxi/charter operations; and specialty services such as instrument and avionics maintenance, painting, overhaul, aerial application, aerial photography, aerial hoists, and pipeline patrol.

Fuel cell: A device capable of generating an electrical current by converting the chemical energy of a fuel (e.g., hydrogen) directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside. It does not contain an intermediate heat cycle, as do most other electrical generation techniques.

General aviation (GA): That portion of civil aviation that encompasses all facets of aviation, except air carriers.

Generator nameplate capacity (installed): The maximum rated output of a generator, prime mover, or other electric power production equipment under specific conditions designated by the manufacturer. Installed generator nameplate capacity is commonly expressed in megawatts (MW) and is usually indicated on a nameplate physically attached to the generator.

Geothermal energy: Hot water or steam extracted from geothermal reservoirs in the earth's crust. Water or steam extracted from geothermal reservoirs can be used for geothermal heat pumps, water heating, or electricity generation.

Grant assurances: Any agreement made between the FAA (on behalf of the United States) and an airport sponsor in that the airport sponsor agrees to certain assurances. In general, the airport sponsor assures it will operate the airport for the use and benefit of the public as an airport for aeronautical purposes. The grant agreement and assurances will apply whether the airport sponsor receives the grant of federal funding or a conveyance of land.

Green pricing: In the case of renewable electricity, green pricing represents a market solution to the various problems associated with regulatory valuation of the nonmarket benefits of renewables. Green pricing programs allow electricity customers to express their willingness to pay for renewable energy development through direct payments on their monthly utility bills.

Ground loop: In geothermal heat pump systems, a series of fluid-filled plastic pipes buried in the shallow ground, or placed in a body of water, near a building. The fluid within the pipes is used to transfer heat between the building and the shallow ground (or water) in order to heat and cool the building.

Ground Support Equipment: Typically associated with the servicing of aircraft during the airport turnaround process consisting of the ground operations that are undertaken from the time the rubber blocks (chocks) are placed in front of the aircraft wheels until the time the blocks are removed and the aircraft is ready to leave the gate. During this period, there are a number of tasks that are performed including loading and unloading passengers and baggage, aircraft cleaning and maintenance, refueling and replenishment of provisions, and other similar services. Other common GSE functions pertain to the servicing and maintenance of the airside infrastructure and airfield of the airport.

Heat pump (geothermal): A heat pump in which the refrigerant exchanges heat (in a heat exchanger) with a fluid circulating through an earth connection medium (ground or ground water). The fluid is contained in a variety of loop (pipe) configurations depending on the temperature of the ground and the ground area available. Loops may be installed horizontally or vertically in the ground or submersed in a body of water.

HVAC: An abbreviation for the heating, ventilation, and air-conditioning system; the system or systems that condition air in a building.

Hydroelectric power: The use of flowing water to produce electrical energy.

Installed Cost: The up-front cost paid by the system owner to construct a generating system.

Internal Rate of Return (IRR): A widely used rate of return for performing economic analysis. This method solves for the interest rate that equates the equivalent worth of an alternative's cash receipts or savings to the equivalent worth of cash expenditures, including investments. The resultant interest rate is termed the IRR.

Inverter: A device that converts direct current electricity (from for example a solar photovoltaic module or array) to alternating current for use directly to operate appliances or to supply power to an electricity grid.

Irradiance: A measure of the intensity of the solar power recorded in W/m^2.

Kilowatt (kW): One thousand watts.

Kilowatt-electric (kWe): One thousand watts of electric capacity.

Kilowatt hour (kWh): A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu.

Landfill gas: Gas that is generated by decomposition of organic material at landfill disposal sites. The average composition of landfill gas is approximately 50% methane and 50% carbon dioxide and water vapor by volume. The methane percentage, however, can vary from 40 to 60%, depending on several factors including waste composition (e.g., carbohydrate and cellulose content). The methane in landfill gas may be vented, flared, combusted to generate electricity or useful thermal energy on-site, or injected into a pipeline for combustion off-site.

Land lease: A long-term land lease, generally for the purpose of erecting a building or buildings, or for constructing improvements to the land to be used by lessee. At the end of lease, the land and all structures and enhancements revert to the owner. Land leases should follow the basic format of the hangar lease and include all of the same references to the airport's rules, regulations, and minimum standards. The land lease price per square foot could vary by location, and possibly by the length of the term, and may also be connected to a business permit or an FBO lease.

Lease: An agreement whereby the owner of real property (landlord or lessor) gives the right of possession to another (tenant or lessee) for a specified period of time (term) and for a specified consideration (rent).

Levelized cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Megawatt (MW): One million watts of electricity.

Megawatt electric (MWe): One million watts of electric capacity.

Megawatt hour (MWh): One thousand kilowatt hours or 1 million watt-hours.

MMBtu: One million (10^6) British thermal units.

Modules: PV cells or an assembly of cells into panels (modules) intended for and shipped for final consumption or to another organization for resale. When exported, incomplete modules and unencapsulated cells are also included. Modules used for space applications are not included.

National Airspace System: It is made up of a network of air navigation facilities, ATC facilities, airports, technology, and appropriate rules and regulations that are needed to operate the system.

Navigational Aids: Any sort of marker that aids the traveler in navigation. In aviation, NAVAIDs include both visible markers and those identified with radar.

Net Metering: The practice of using a single meter to measure consumption and generation of electricity by a small generation facility (such as a house with a wind or solar photovoltaic system). The net energy produced or consumed is purchased from or sold to the power provider, respectively.

Net Present Value: The value of a personal portfolio, product, or investment after depreciation and interest on debt capital are subtracted from operating income. It can also be thought of as the equivalent worth of all cash flows relative to a base point called the present.

Non-aeronautical Uses: Any activity that is not directly involved with, made possible, or required for the operation of aircraft or that contributes to or is required for the safety of such operations.

Obstruction: Any object or natural growth, terrain, or permanent or temporary construction or alteration, including equipment or materials used therein, the height of which exceed the standards established in Subpart C of FAR Part 77, Objects Affecting Navigable Airspace.

Ocean energy systems: Energy conversion technologies that harness the energy in tides, waves, and thermal gradients in the oceans.

Off peak: Period of relatively low system demand. These periods often occur in daily, weekly, and seasonal patterns; these off-peak periods differ for each individual electric utility.

Operations and Maintenance: A set of activities, most of them technical in nature, which enable power generation facilities to perform their task of producing energy in compliance with applicable rules and regulations.

Passenger Facility Charge (PFC): The PFC program, first authorized by the Aviation Safety and Capacity Expansion Act of 1990 and now codified under Section 40117 of Title 49 U.S.C., provides a source of additional capital to improve, expand, and repair the nation's airport infrastructure. The legislation allows public agencies controlling commercial service airports to charge enplaning passengers using the airport a facility charge. The FAA must approve any facility charges imposed on enplaning passengers.

Payback Period: The amount of time required before the savings resulting from the system equal the system cost.

Peak Demand: The maximum load during a specified period of time.

Peak Shaving: The process of implementing measures to reduce peak power demands on a system.

Photovoltaic and solar thermal energy (as used at electric utilities): Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted at electric utilities into electricity by means of solar (PV) cells or concentrating (focusing) collectors.

Power purchase agreements (PPAs): PPA is a contract between a buyer and seller of energy that obligates the party to deliver and pay for energy for a pre-determined price and term. PPAs guarantee a future revenue stream and therefore can be an important component to securing project financing.

Rebate program: A utility company-sponsored conservation program whereby the utility company returns a portion of the purchase price cost when a more energy-efficient refrigerator, water heater, air conditioner, or other appliance is purchased.

Reliability (electric system): A measure of the ability of the system to continue operation while some lines or generators are out of service. Reliability deals with the performance of the system under stress.

Renewable Energy Certificates (RECs): RECs represent the environmental attributes of electricity generated through a qualifying renewable energy resource. One REC is issued for every 1 megawatt-hour (MWh) of electricity produced by the qualifying source. Since renewable electricity fed into the electric grid is distributed according to physical laws rather than contractual agreements, RECs help account for who can claim the use of renewable electricity. A State Renewable Portfolio Standard (RPS) typically requires the utilities to procure a certain amount of RECs to demonstrate compliance with their renewable energy requirement. RECs can be bought and sold as commodities in the market, and are issued and tracked by various Generation Information Systems (GIS) that operate within the U.S. electric grid. RECs are also known as green tags, green certificates, or tradable renewable certificates.

Renewable energy resources: Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

Renewable Portfolio Standards (RPSs): RPSs require utilities to use or procure renewable energy or RECs to account for a certain percentage of their retail electricity sales—or a certain amount of generating capacity—according to a specified schedule. (Renewable portfolio goals are similar to RPS policies, but goals are not legally binding.) Most U.S. states have established an RPS. The term "set-aside" or "carve-out" refers to a provision within an RPS that requires utilities to use a specific renewable resource (usually solar energy) to account for a certain percentage of their retail electricity sales (or a certain amount of generating capacity) according to a set schedule.

Return on investment (ROI): A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio.

Run-of-river hydroelectric plant: A low-head plant using the flow of a stream as it occurs and having little or no reservoir capacity for storage.

Runway Protection Zone (RPZ): A trapezoid-shaped area off the runway end that enhances the protection of people and property on the ground.

Runway Safety Area (RSA): A defined surface surrounding the runway, prepared or suitable for reducing the risk of damage to airplanes in the event of an undershoot, overshoot, or excursion from the runway.

Service area: The territory in which a utility system or distributor is authorized to provide service to consumers.

Solar energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Solar thermal panels: A system that actively concentrates thermal energy from the sun by means of solar collector panels. The panels typically consist of flat, sun-oriented boxes with transparent covers, containing water tubes of air baffles under a blackened heat absorbent panel. The energy is usually used for space heating, for water heating, and for heating swimming pools.

Tariff: A published volume of rate schedules and general terms and conditions under which a product or service will be supplied.

Tax Incentives: Tax incentives include tax credits, deductions, and exemptions. They can be applied to corporate, personal, property, and sales tax liability. These incentives are available in some states to individuals and organizations that purchase and install eligible renewable energy or energy efficiency equipment, or to construct green buildings. In a few cases, the incentive is based on the amount of energy produced by an eligible facility. Some states allow the tax credit only if a corporation has invested a minimum amount in an eligible project. Typically, there is a maximum limit on the dollar amount of the credit or deduction. In recent years, the federal government has offered corporate tax incentives for renewables and energy efficiency.

Third party: Third-party transactions are arms-length transactions between non-affiliated firms.

Time of day rate: The rate charged by an electric utility for service to various classes of customers. The rate reflects the different costs of providing the service at different times of the day.

Transmission line (electric): A system of structures, wires, insulators and associated hardware that carry electric energy from one point to another in an electric power system. Lines are operated at relatively high voltages varying from 69 kV up to 765 kV and are capable of transmitting large quantities of electricity over long distances.

Useful Life: An estimate of how long one can expect to use an income-producing item in a trade or business setting. Useful life usually refers to the duration for which the item will be useful (to the business), and not how long the property will actually last.

Waste materials: Otherwise discarded combustible materials that, when burned, produce energy for such purposes as space heating and electric power generation. The size of the waste may be reduced by shredders, grinders, or hammermills. Noncombustible materials, if any, may be removed. The waste may be dried and then burned, either alone or in combination with fossil fuels.

Wholesale power market: The purchase and sale of electricity from generators to resellers (who sell to retail customers), along with the ancillary services needed to maintain reliability and power quality at the transmission level.

Wind energy: Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

Wind turbine: Wind energy conversion device that produces electricity; typically three blades rotating about a horizontal axis and positioned up-wind of the supporting tower.

Wood pellets: Saw dust compressed into uniform diameter pellets to be burned in a heating stove.

Source of definitions: Energy Information Administration: http://www.eia.gov/tools/glossary/, U.S. Department of Energy: http://energy.gov/eere/energybasics/articles/glossary-energy-related-terms#R, the Database of State Incentives for Renewable Energy: http://www.dsireusa.org/support/glossary/, as well as several other Department of Energy and Federal Aviation documents and sources.

References

1. Kramer, L. 2010. *ACRP Synthesis 19: Airport Revenue Diversification.* Transportation Research Board of the National Academies, Washington DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_syn_019.pdf
2. U.S. Department of Transportation. 2014. Report to Congress: National Plan of Integrated Airport Systems (NPIAS), 2015–2019. Report of the Secretary of Transportation to the United States Congress Pursuant to Title 49 U.S. Code, Section 47103. http://www.faa.gov/airports/planning_capacity/npias/reports.
3. ACI-NA Survey. 2003. Airport Ownership.
4. Reimer, D. and J. Putnam. 2009. *ACRP Legal Research Digest 7: Airport Governance and Ownership.* Transportation Research Board of the National Academies, Washington, DC.
5. Kramer, L. 2010. *ACRP Synthesis 19: Airport Revenue Diversification.* Transportation Research Board of the National Academies, Washington DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_syn_019.pdf
6. U.S. Energy Information Administration. 2015. Short-term Energy Outlook. Energy Information Administration. March 10, 2015. http://www.eia.gov/forecasts/steo/
7. Energy Information Administration. 2014. Electricity Data Browser. Energy Information Administration. Accessed on September 8, 2014. http://www.eia.gov/electricity/data/browser/
8. Energy Information Administration. 2015. Energy Basics. Energy Information Administration. Accessed March 24, 2015. http://www.eia.gov/energyexplained/index.cfm
9. National Renewable Energy Laboratory. 2014. Renewable Energy Basics. Accessed on September 8, 2014. http://www.nrel.gov/learning/re_solar.html
10. Solar Energy Industry Association. 2014. U.S. Solar Market Insight Report – 2013. http://www.seia.org/sites/default/files/resources/5jBprenCY92013ye.pdf
11. U.S. Energy Information Administration. 2012. Annual Energy Review: 2011. September 2012. Accessed on September 8, 2014. http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf
12. U.S. Energy Information Administration. 2014. Annual Energy Outlook. Energy Information Administration. May 7, 2014. http://www.eia.gov/forecasts/aeo/
13. U.S. Energy Information Administration. 2014. Geothermal Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=geothermal_home
14. Energy Information Administration. 2014. Geothermal Power Plants. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=geothermal_power_plants
15. National Renewable Energy Laboratory. 2014. Geothermal Electricity. Accessed on December 15, 2014. http://www.nrel.gov/learning/re_geo_elec_production.html
16. Calpine Corporation. 2014. Company website. Accessed on September 12, 2014. http://www.geysers.com/geothermal.aspx
17. Geothermal Energy Association. 2014. 2014 Annual U.S. and Global Geothermal Power Production Report. http://geo-energy.org/events/2014%20Annual%20US%20&%20Global%20Geothermal%20Power%20Production%20Report%20Final.pdf
18. Department of Energy. 2013. Annual Report: Geothermal Technologies Office. February 2014. http://www1.eere.energy.gov/geothermal/pdfs/gto-annual-report2013.pdf
19. U.S. Energy Information Administration. 2014. Geothermal Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=geothermal_heat_pumps
20. Federal Energy Management Program. 2003. "Preliminary Screening for Project Feasibility and Applications for Geothermal Heat Pump Retrofit Projects." Washington, D.C. 3 pp. Accessed December 26, 2014: http://btric.ornl.gov/pdfs/com_ghp_screening_femp.pdf.
21. National Renewable Energy Laboratory. 2014. Technical Feasibility Study for Deployment of Ground-Source Heat Pump Systems: Portsmouth Naval Shipyard, Kittery, Maine. Technical Report, NREL/TP-6A10-62353. November 2014. http://www.nrel.gov/docs/fy15osti/62353.pdf

22. Department of Defense. 2007. Report to Congress: Ground-Source Heat Pumps at Department of Defense Facilities. http://www.acq.osd.mil/ie/energy/library/GSHP-Report_JAN242007.pdf
23. US Energy Information Administration. 2014. Energy Explained. Accessed on November 9, 2014. http://www.eia.gov/energyexplained/index.cfm?page=biomass_home
24. National Renewable Energy Laboratory. 2014. Biomass Basics. Accessed on December 15, 2014. http://www.nrel.gov/learning/re_biomass.html
25. Miller, B. 2012. *ACRP Report 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting.* Transportation Research Board of the National Academies, Washington, DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_060.pdf
26. Miller, B. 2013. *ACRP Report 83: Assessing Opportunities for Alternative Jet Fuel Distribution Programs.* Transportation Research Board of the National Academies. Washington DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_083.pdf
27. U.S. Energy Information Administration. 2014. Waste to Energy Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=biomass_waste_to_energy
28. National Renewable Energy Laboratory. 2014. Wind Energy Basics. Accessed on December 15, 2014. http://www.nrel.gov/learning/re_wind.html
29. Department of Energy. 2008. "20% Wind Energy by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply," Office of Energy Efficiency and Renewable Energy (EERE), DOE/GO-102008-2567, July 2008: http://www.osti.gov/bridge
30. Department of Energy. 2011. "A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States," February 2011.
31. Department of Energy. 2008. "20% Wind Energy by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply," DOE/GO-102008-2567, July 2008: http://www.osti.gov/bridge
32. Department of Energy. 2013. "Large-Scale Renewable Energy Guide, Developing Renewable Energy Projects Larger Than 10 MWs at Federal Facilities," Federal Energy Management Program, DOE/GO-102013-3915, March 2013: www.femp.energy.gov
33. American Wind Energy Association. 2014. Monthly Newsletter, March 14, 2013.
34. American Wind Energy Association. 2014. Wind 101: the basics of wind energy. Accessed on November 10, 2014. http://www.awea.org/Resources/Content.aspx?ItemNumber=90
35. U.S. Energy Information Administration. 2014. Energy Explained. Accessed on November 11, 2014. http://www.eia.gov/energyexplained/index.cfm?page=hydropower_home
36. U.S. Energy Information Administration. 2014. Hydropower Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=hydropower_home
37. Federal Energy Regulatory Commission. 2014. Hydropower Regulatory Efficiency Act of 2013. Accessed on November 11, 2014. http://www.ferc.gov/industries/hydropower/indus-act/efficiency-act.asp
38. U.S. Energy Information Administration. 2014. Wave Power Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=hydropower_wave
39. U.S. Energy Information Administration. 2014. Tidal Power Explained. Accessed on December 15, 2014. http://www.eia.gov/energyexplained/index.cfm?page=hydropower_tidal
40. US Department of Energy. 2014. Energy Basics: Fuel Cells. Accessed on November 11, 2014. http://energy.gov/eere/energybasics/articles/fuel-cell-basics
41. McGormley, R. 2013. *ACRP Report 43: Guidebook of Practices for Improving Environmental Performance at Small Airports.* Transportation Research Board of the National Academies, Washington DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_043.pdf
42. Mandle. P. 2009. *ACRP Report 24: Guidebook for Evaluating Airport Parking Strategies and Supporting Technologies.* Transportation Research Board of the National Academies, Washington, DC. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_024.pdf
43. National Renewable Energy Laboratory. 2014. Developer Network: Utility Rates. Accessed on December 22, 2014. http://developer.nrel.gov/docs/electricity/utility-rates-v3/
44. Lazard Investments. 2014. Levelized Cost of Energy – Version 8.0. September 2014. http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf
45. Department of Energy and North Carolina Clean Energy Technology Center. 2014. Database of State Incentives for Renewables and Efficiency. Accessed on December 15, 2014. http://www.dsireusa.org/incentives/index.cfm?state=us
46. Wiser, R, C. Namovicz, M. Gielecki, and R. Smith. 2007. Renewable Portfolio Standards: A Factual Introduction to Experience in the United States. Lawrence Berkley National Laboratory. Environmental Energy Technologies Division. April 2007. http://emp.lbl.gov/sites/all/files/lbnl%20-%2062569.pdf
47. U.S. Environmental Protection Agency. 2014. Green Power Partnership Website. Accessed December 11, 2014. http://www.epa.gov/greenpower/
48. Federal Aviation Administration. 2012. Memorandum: *Draft Interim Guidance on Energy Efficiency.* August 7, 2012.

49. Database of State Incentives for Renewables and Efficiency. 2014. Accessed on December 11, 2014. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02R
50. Department of Energy. 2014. Financing Solutions. Accessed on December 17, 2014. http://energy.gov/eere/wipo/financing-solutions
51. Federal Aviation Administration. 2012. Memorandum: *Draft Interim Guidance on Energy Efficiency.* August 7, 2012.
52. Federal Aviation Administration. 2013. Draft FAA Order 1050.1F. Published on 8/14/13. Accessed on December 29, 2014. http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/draft_faa_order/
53. Ho, C. and C. Sims. 2012. Report on Manchester Airport Solar Project.
54. Federal Aviation Administration. 2013. Draft FAA Order 1050.1F. Published on 8/14/13. Accessed on December 29, 2014. http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/draft_faa_order/
55. Federal Aviation Administration. 2014. Assurances: Airport Sponsors. Accessed on December 29, 2104. http://www.faa.gov/airports/aip/grant_assurances/media/airport-sponsor-assurances-aip.pdf
56. Federal Aviation Administration. 2012. Interim Guidance on Land Uses within a Runway Protection Zone. September 27, 2012. https://www.faa.gov/airports/planning_capacity/media/interimLandUseRPZGuidance.pdf
57. Reimer, D. and J. Putnam. 2009. *ACRP Legal Research Digest 7: Airport Governance and Ownership.* Transportation Research Board of the National Academies, Washington, DC.
58. Federal Aviation Administration. 2012. Memorandum: *Draft Interim Guidance on Energy Efficiency.* August 7, 2012.
59. National Renewable Energy Laboratory. 2013. Energy Analysis. Accessed on December 23, 2014. Updated August 2013. http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html
60. Federal Aviation Administration. 2012. Memorandum: *Draft Interim Guidance on Energy Efficiency.* August 7, 2012.
61. National Renewable Energy Laboratory. 2014. PVWatts Calculator. Accessed on December 22, 2014. http://pvwatts.nrel.gov/pvwatts.php
62. Goetzler, W., R. Zogg, H. Lilse, and J. Burgos. 2009. Ground-Source Heat Pumps: Overview of Market Status, Barriers to Adoption, and Options for Overcoming Barriers. Prepared by Navigant Consulting for U.S. Department of Energy, Geothermal Technologies Program. February 3, 2009. https://www1.eere.energy.gov/geothermal/pdfs/gshp_overview.pdf
63. Matley, R. 2013. "Heat Pumps: An alternative to oil heat in the Northeast." Rocky Mountain Institute. March 2013. http://www.rmi.org/cms/Download.aspx?id=10410&file=2013-05_HeatPumps.pdf
64. Martin, M. A., D. J. Durfee, and P. J. Hughes. 1999. Comparing maintenance costs of geothermal heat pump systems with other HVAC systems in Lincoln (NB) public schools: Repair, service and corrective actions, ASHRAE Trans, 1999, Vol. 105, Part 2, #SE-99-20-04, 1208–1215.
65. Newton, A. 2014. Personal Communication. Project Engineer. Portland International Jetport. November 5, 2014.
66. National Renewable Energy Laboratory. 2014. Cost of Renewable Energy Spreadsheet Tool. Fuel Cells. https://financere.nrel.gov/finance/files/nrel_crest_fuel-cell_version1-3_mac.xlsx
67. *See* PLR 200827023, July 4, 2008. Note, however that PLRs may not be relied upon or cited as precedent by any party other than the person requesting the PLR.
68. Federal Aviation Administration. 1999. FAA Airport Benefit Cost Analysis Guidance. Office of Policy and Plans. December 15, 1999. https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/1999_FAA_Airport_Benefit_Cost_Analysis_Guidance.pdf
69. Federal Aviation Administration. 2013. Draft FAA Order 1050.1F. Published on 8/14/13. Accessed on December 29, 2014. http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/draft_faa_order/
70. Federal Aviation Administration. 2010. Technical Guidance for Evaluating Selected Solar Technologies at Airport. APP-400. November 2010.
71. Federal Aviation Administration. 2013. Interim Policy, FAA Review of Solar Energy System Projects on Federally-Obligated Airport. October 23, 2013. https://www.federalregister.gov/articles/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports
72. Federal Aviation Administration. 2014. Obstruction Evaluation Airport Airspace Analysis. Accessed on December 29, 2014. https://oeaaa.faa.gov/oeaaa/external/portal.jsp

APPENDIX A

List of Airport Solar Projects in the United States

Airport	Code	State	System Size	Location	Ownership	Date
Alamogordo	ALM	NM	8 kW	Ground-mounted	Airport	2008
Albuquerque	ABQ	NM	146 kW	Parking Garage	Airport	2009
			438 kW	Parking Garage	Airport	2010
			365 kW	Parking Garage	Airport	2011
Austin	AUS	TX	84 kW	Ground near Cargo	Airport	1998
			27 kW	Carports, Taxi Area	Airport	2000
Bagdad	E51	AZ	15.5 MW	Ground (adjacent to airport)	Third Party	2011
Bakersfield	BFL	CA	900 kW	Ground	Third Party	2009
Baltimore Wash	BWI	MD	505 kW	Parking Garage		
Barnstable	HYA	MA	6 MW	Ground	Third Party	2014
Boston	BOS	MA	367 kW	Terminal A Roof and Satellite	Third Party	2011
			200 kW	Terminal B Parking Garage	Airport	2010
			81 kW	Economy Parking Garage	Airport	2011
			150 kW	ConRAC	Airport	2013
			50 kW	Green Bus Depot	Airport	2014
Burbank	BUR	CA	225 kW	Hangar roof	Tenant	2008
Burlington	BVT	VT	1.45 MW	Ground	VT National Guard	2013
			500 kW	Parking Garage	Utility	2015
Charlotte	CLT	NC	306 kW	Roof of Administrative Office	Third Party	2010
			120 kW		Airport	2012
Chattanooga	CHA	TN	1 MW	Ground	Airport	2010
			1.1 MW	Ground	Airport	2011
Dallas	DFW	TX	187 kW	Roof of Administrative Office	Airport	2011
Dane County	MSN	WI	100 kW	Roof Maintenance Bldg	Airport	2014

Airport	Code	State	System Size	Location	Ownership	Date
Denver	DIA	CO	2 MW	Ground	Third Party	2008
			1.6 MW	Ground	Third Party	2010
			4.4 MW	Ground	Third Party	2011
			2 MW	Ground	Third Party	2014
			262 kW	Roof - Hertz	Tenant	2014
Ft Myers / Page Field	FMY	FL	200 kW	Roof Corporate Hangar	Airport	2012
Fresno	FAT	CA	2.4 MW	Ground	Third Party	2008
Gainesville	GNV	FL	292 kW	Terminal Roof	Airport	2012
Garfield County	RIL	CO	858 kW	Ground	Third Party	2011
Glendale	GEU	AZ	172 kW	Ground	Utility	2001
Indianapolis	IND	IN	25 MW	Ground	Third Party	2013
Hanscom	BED	MA	45 kW	Terminal Roof	Airport	2011
Hilo	ITO	HI	111 kW	Terminal Roof	Airport	2012
Houston	IAH	TX	60 kW	Terminal Roof	Airport	2009
Jefferson County	TWD	WA	16.7 kW	Ground (power NAVAIDs)	Airport	2012
Kahului	OGG	HI	327 kW	Cargo Bldg Roof	Airport	2012
			42 kW	T-hangar Roof	Airport	2012
Kona	KOA	HI	61 kW	Wastewater Plant	Airport	2012
Lanai	LNY	HI	117 kW	Terminal Roof	Airport	2012
Lakeland	LAL	FL	6 MW	Ground	Third Party	2012
Las Cruces	LRU	NM	12 MW	Ground (City land adjacent to airport)	Third Party	2012
Lihue	LIH	HI	338 kW	Terminal Roof	Airport	2012
Long Beach	LGB	CA	6.6 kW	Solar Trees	Airport	2008
MacArthur / Islip	ISP	NY	13 kW	Terminal	Airport	2010
Manchester	MHT	NH	530 kW	Parking Garage	Airport	2012
McCall	MYL	ID	9.075 kW	Roof Administrative Bldg	Airport	2012
McCollum	RYY	GA	140 kW	Two GA Hangars	Tenant	2011
Newark	EWR	NJ	3.3 MW	Three FedEx Bldgs	Tenant	2012
			972 KW	Four Airport Bldgs	Third Party	2014
			299 kW	Hertz - Building	Tenant	2014
Northampton	7B2	MA	10 kW	Hangar Roof	Airport	2011
Oakland	OAK	CA	756 kW	Ground Airfield	Third Party	2007
			904 kW	Roof FedEx Bldg	Tenant	2005
Oakland County	PTK	MI	5 kW	Terminal Roof	Airport	2011
Outagamie County	ATW	WI	25 kW	GA Terminal Roof	Airport	2013
Phoenix	PHX	AZ	4.9 MW	Rental Car Roof	Third Party	2012
			1.29 MW	Economy Parking Roof	Third Party	2012
Person County	TDF	NC	3 MW	Ground Adjacent to Airport	Third Party	2012

Airport	Code	State	System Size	Location	Ownership	Date
Prescott – Love	PRC	AZ	3.6 MW	Airfield	Third Party	2005
Reagan	DCA	VA	10 kW	Terminal Roof	Tenant	2011
Redding	RDD	CA	693 kW	Airfield	Airport	2010
Redmond	RDM	OR	44 kW	Terminal Roof	Airport	2010
Reno-Tahoe	REN	NV	135 kW	Ground – at ARFF	Airport	2012
Rockford	RFD	IL	3 MW	Airfield near RPZ	Third Party	2012
Rogue Valley	MFR	OR	15 kW	Parking Lights	Airport	2012
			25 kW	Walkway Canopy	Airport	2013
San Antonio	SAT	TX	300 kW	Parking Garage	Airport	2010
Santa Barbara	SBA	CA	159 kW	Rental Car Carports	Airport	2009
San Bernardino	SBD	CA	632 kW	Terminal Roof	Airport	2011
San Diego	SAN	CA	630 kW	Terminal Roof	Third Party	2015
San Francisco	SFO	CA	500 kW	Terminal Roof	Airport	2007
			20 kW	Administrative Bldg	Airport	2001
San Jose	SJC	CA	1.12 MW	Rental Car Rooftop	Airport	2010
San Rafael	CA35	CA	972 kW	Hangar Buildings	Airport	2012
Shelby County	EHO	NC	1 MW	Ground at entrance	Third Party	2010
Smyrna	MQY	TN	1 MW	Ground in office park	Third Party	2012
St. Louis	STL	MO	152 kW	Hertz - Roof	Tenant	2014
St. Thomas	TIST	VI	450 kW	Ground, Airfield	Airport	2011
Tallahassee	TLH	FL	25 kW	Terminal Roof	Airport	2012
Taylorville	TAZ	IL	19 kW	Ground	Airport	2012
Teterboro	TET	NJ	697 kW	Hangar Rooftops	Third Party	2011
Tucson	TUS	AZ	1 MW	Parking Canopies	Airport	2013
Waimea-Kohala	MUE	HI	21 kW	Terminal Roof	Airport	2012
Walla Walla	ALW	WA	75 kW	Terminal Building	Airport	2012
Warren Field	OCW	NC	5 MW	Airfield	Third Party	2014
Wyandot - Seneca	16G	OH	12 MW	Airfield (adjacent to airport)	Third Party	2010
Yuma	YUM	AZ	500 kW	Shaded Parking	Airport	2010

APPENDIX B

Biofuel Feedstock Propagation Future Opportunity

Growing biofuel feedstock on airport lands is a potential future revenue opportunity for airports. This opportunity has arisen from otherwise disparate developments. First, the aviation industry is focusing efforts in developing alternative jet fuels from oil-rich plant stocks. While this market is currently in a nascent phase, demand for feedstock is predicted to expand in coming years and airports could be in a position to provide a cost-effective supply.

Second, researchers assessing land uses that represent a wildlife hazard risk have determined that turf grass, which covers the vast majority of airport lands, is a high risk particularly because it is preferred by certain large birds such as Canada geese. It is recommended that turf be converted to other cover types and specific biofuel feedstock crops have been determined to reduce risks of wildlife hazards.

Wildlife Strikes

Collisions between wildlife and aircraft (wildlife strikes) are a serious concern for both economic and safety reasons (DeVault et al. 2013a). Wildlife strikes cost the civil aviation industry in the United States nearly $1 billion annually, and over 255 people were killed in wildlife strikes worldwide from 1988–2013 (Dolbeer et al. 2014). Roughly 70% of wildlife strikes to aircraft occur ≤152 m above ground level, thus in the airport environment (Dolbeer 2011). It is clear that understanding the causal factors contributing to wildlife-aircraft collisions at airports and developing solutions to reduce the likelihood of such collisions are critical challenges facing wildlife managers and aviation officials (Blackwell et al. 2009).

Habitat management is the most important long-term component of an integrated approach to reducing wildlife hazards at airports (DeVault and Washburn 2013, Belant and Ayers 2014). Historically, the principal land cover at airports has been turf grass. In addition to the linear strips of turf grass normally present adjacent to air-operations areas, many airports (in the United States and abroad) contain large expanses of turf grass in outlying areas (Washburn and Seamans 2013). In the contiguous United States, 39–50% of airport land cover is composed of turf grass, and these airport grasslands collectively cover well over 3,300 km^2 (DeVault et al. 2012).

Although turf grass is useful in some airport areas and has a place in habitat management at airports (especially alongside runways and taxiways), large expanses of turf grass can attract hazardous birds like Canada geese and European starlings (DeVault et al. 2011), and are expensive for airports to maintain. Further, maintenance of large grasslands conflicts with recent industry initiatives promoting “greener” airports. Ongoing research challenges the longstanding paradigm that turf grass should be the dominant land cover at airports (DeVault et al. 2013b, Martin et al. 2013). Some researchers have suggested that with careful planning, much of the turfgrass acreage currently present at airports could be converted to more productive land uses—such as solar arrays and biofuel production—without increasing the risk of damaging wildlife strikes with aircraft (DeVault et al. 2012, 2013b, Martin et al. 2013). Rather than consume resources and produce greenhouse gas emissions, these alternative land uses could generate revenue and renewable energy for airports.

Research on Biofuel Feedstock

Biologists from the USDA, Wildlife Services, National Wildlife Research Center and Mississippi State University are conducting research on several fronts to identify safe alternatives to turf grass at airports from a wildlife-strike perspective. Schmidt et al. (2013) studied bird use of areas managed for native warm season grasses (NWSG), a cellulosic biofuel (Tilman et al. 2006), compared to nearby airfield grasslands. They found that birds of species categorized as 'moderate' to 'extremely high' with regard to hazard level to aircraft accounted for only 2% of all birds observed in NWSG areas, and concluded that NWSG might be considered a viable land use adjacent to airfields in some regions.

In addition to these studies, several ongoing efforts by this research group are addressing wildlife use of renewable energy production efforts at airports. In Mississippi, a multi-year field study assessing wildlife use of fields containing switchgrass or a NWSG mixture found that use by birds and mammals considered hazardous to aircraft was low overall. Seasonal variability in hazardous species use occurred in both vegetation types but overall appeared lower in switchgrass fields. Also, a project funded by the U.S. Department of Defense began in 2014 that will demonstrate and validate the use of monoculture switchgrass at military installations in the eastern United States as a means of reducing wildlife strike risk and lowering costs associated with maintaining large turf-grass areas. Finally, a study is just underway in North Carolina that will investigate use of oilseed crops (e.g., camelina) by birds and large mammals at several general aviation airports.

Conclusions

Although most researchers agree that renewable energy production should be increased, this "scaling-up" of production raises a number of environmental issues, notably adverse effects on wildlife and competition with human food production. However, airport lands are mostly unsuitable for wildlife conservation and commodity production due to the increased risk of wildlife-aircraft collisions often associated with these land uses. Also, airports offer one of the few land uses where reductions in wildlife abundance and habitat quality are necessary and socially acceptable. Thus, locating renewable energy projects at airports could help mitigate many of the challenges currently facing renewable-energy policy makers, developers, and conservationists (DeVault et al. 2012, 2013b). The recent and ongoing studies described here suggest that some types of renewable energy production can be compatible with safe airport operation, and in some cases might actually reduce the risk of wildlife strikes from that posed by large expanses of turf grass. A shift in airport land-management paradigms on a large scale from large expanses of turf grass to alternative land covers could play a meaningful role in regional renewable energy strategies.

References

Belant, J. L., and C. R. Ayers. 2014. *ACRP Synthesis 52: Habitat Management to Deter Wildlife at Airports.* Transportation Research Board of the National Academies, Washington, DC.

Blackwell, B. F., T. L. DeVault, E. Fernández-Juricic, and R. A. Dolbeer. 2009. Wildlife Collisions with Aircraft: A Missing Component of Land-Use Planning for Airports. *Landscape and Urban Planning* 93:1–9.

DeVault, T. L., M. J. Begier, J. L. Belant, B. F. Blackwell, R. A. Dolbeer, J. A. Martin, T. W. Seamans, and B. E. Washburn. 2013b. Rethinking Airport Land-Cover Paradigms: Agriculture, Grass, and Wildlife Hazards. *Human-Wildlife Interactions* 7:10–15.

DeVault, T. L., J. L. Belant, B. F. Blackwell, J. A. Martin, J. A. Schmidt, L. W. Burger, Jr., and J. W. Patterson, Jr. 2012. Airports Offer Unrealized Potential for Alternative Energy Production. *Environmental Management* 49:517–522.

DeVault, T. L., J. L. Belant, B. F. Blackwell, and T. W. Seamans. 2011. Interspecific Variation in Wildlife Hazards To Aircraft: Implications for Airport Wildlife Management. *Wildlife Society Bulletin* 35:394–402.

DeVault, T. L., B. F. Blackwell, and J. L. Belant, eds. 2013a. *Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions through Science-Based Management.* Johns Hopkins University Press, Baltimore, MD.

DeVault, T. L., and B. E. Washburn. 2013. Identification and Management of Wildlife Food Resources at Airports. Pages 79–90 *in: Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions through Science-Based Management.* T. L. DeVault, B. F. Blackwell, and J. L. Belant, eds. Johns Hopkins University Press, Baltimore.

Dolbeer, R. A. 2011. Increasing Trend of Damaging Bird Strikes with Aircraft Outside the Airport Boundary: Implications for Mitigation Measures. *Human-Wildlife Interactions* 5:235–248.

Dolbeer, R. A., S. E. Wright, J. R. Weller, and M. J. Begier. 2014. *Wildlife Strikes to Civil Aircraft in the United States 1990–2013.* National Wildlife Strike Database Serial Report Number 20. Federal Aviation Administration, Office of Airport Safety and Standards, Washington, DC. 98 pp.

Martin, J. A., T. J. Conkling, J. L. Belant, K. M. Biondi, B. F. Blackwell, T. L. DeVault, E. Fernández-Juricic, P. M. Schmidt, and T. W. Seamans. 2013. Wildlife Conservation and Alternative Land Uses at Airports. Pages 117–125 *in: Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions through Science-Based Management.* T. L. DeVault, B. F. Blackwell, and J. L. Belant, eds. Johns Hopkins University Press, Baltimore, MD.

Pennington, D., M. C. Gould, M. Seamon, W. Knudson, P. Gross, and T. McLean. 2012. Expanding Bioenergy Crops to Non-Traditional Lands in Michigan—Final Report. Michigan State University Extension. Based on work supported by the Department of Energy, Award no. DE-EE0000753. 66 pp.

Schmidt, J. A., B. E. Washburn, T. L. DeVault, T. W. Seamans, and P. M. Schmidt. 2013. Do Native Warm-Season Grasslands Near Airports Increase Bird Strike Hazards? *American Midland Naturalist* 170:144–157.

Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. *Science* 314:1598–1600

Washburn, B. E., and T. W. Seamans. 2013. Managing Turfgrass to Reduce Wildlife Hazards At Airports. Pages 105–114 *in: Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions through Science-Based Management.* T. L. DeVault, B. F. Blackwell, and J. L. Belant, eds. Johns Hopkins University Press, Baltimore, MD.

APPENDIX C

Renewable Energy Funding Matrix

Program	FAA/APP Program Manager	Program Purpose	Eligible Activities	Program Effectiveness Criteria	Eligible Airports	Additional Requirements Above AIP Grant Assurances
Voluntary Airport Low Emissions Program (VALE)	APP-400 Patrick Magnotta	Clean airport technology and alternative fuel projects	Airport clean infrastructure and airport dedicated vehicles	Emission reductions per dollar spent	Commercial service airports in air quality nonattainment and maintenance areas	4 special conditions on vehicle use, labeling, reporting, and replacement
Airport Energy Efficiency Program (Section 512)	APP-400 Patrick Magnotta	Increase the energy efficiency of airport power sources	Energy efficient on-airport electrical energy production: Solar, geothermal, hydrogen, etc.	Energy savings per dollars spent	Eligible public use airports	Comprehensive airport energy assessments (waived for LED airfield lighting, energy efficient upgrades during terminal improvement, and participation in the VALE and ZEV Pilot Programs)
Airport Sustainability Plans	APP-400 Patrick Magnotta	Making sustainability a core element of airport planning	Sustainability planning, either within an airport master plan or a stand-alone study.	Measurable sustainability initiatives, effective tracking and implementation plans, and sustainability performance improvements	Eligible public use airports	Recycling plans - required in all new Master Plans and Master Plan Updates
Zero Emissions Vehicle and Infrastructure Pilot Program	APP-400 Patrick Magnotta	Zero-emission on-road vehicles and supporting fuel infrastructure	- Electric drive and hydrogen-fuel vehicles - Stand-alone infrastructure included (e.g., recharging stations)	Emission reductions per dollar spent	Eligible public use airports in air quality nonattainment and maintenance areas. If insufficient interest, airports in attainment become eligible	- No GSE, only on-road vehicles (LDVs, LDTs, HDVs) - No leasing
Airport Improvement Program (AIP) & Passenger Facility Charge Program (PFC)	APP-500 Nancy Williams (AIP) Joe Hebert (PFC)	Airport development, more efficient operations, and reduced costs	Related activities include energy efficiency, LED lights, recycling, and energy assessments	Justified airport improvement priority	Eligible public use airports	Numerous special grant assurances

Program	Grant Application	Submission Process	Application Deadline	AIP Handbook Guidance	Program Guidance
Voluntary Airport Low Emissions Program (VALE)	Specific VALE application in addition to AIP grant request	ADO/Region to APP-400	Fiscal year for AIP, Rolling deadline for PFC	Chapter 6, Section 5, p. 6-26, and Appendix S, Table S-1	- VALE Technical Report (12/2/2010) with application procedures in Chapter 2 - EPA air quality credit guidance
Airport Energy Efficiency Program (Section 512)	- Standard AIP grant request - Energy Assessment with a comprehensive list of energy efficiency practices that demonstrates project energy savings - Description of the project and energy efficiency benefits	ADO/Region to APP-400	None	Chapter 6, Section 7, p. 6-29, and Appendix S, Table S-1	- Pending guidance memorandum (contact APP-400 until then) - Pending update to “Solar Guide”
Airport Sustainability Plans	- Standard AIP planning grant request - Project description/scope of work that includes items in FAA’s interim guidance on sustainability plans	ADO/Region to APP-400	None	Chapter 3, Section 11, p. 3-53, and Appendix E, E-3, and Appendix S, Table S-1	Interim Guidance (5/27/2010)
Zero Emissions Vehicle and Infrastructure Pilot Program	Specific ZEV application in addition to AIP grant request	ADO/Region to APP-400	None	Chapter 6, Section 6, p. 6-28, and Appendix S, Table S-1	Technical Guidance (12/13/2012) with application procedures in Appendix A
Airport Improvement Program (AIP) & Passenger Facility Charge Program (PFC)	Standard AIP grant application process	ADO/Region to APP-500	Fiscal year for AIP, Rolling deadline for PFC	Entire AIP Handbook	

Program	AIP Budget Categories	AIP Budgeted Amount	PFC Eligibility	Note	Grant Activity	Federal Share
Voluntary Airport Low Emissions Program (VALE)	Entitlements and Discretionary (primarily “Noise & Environmental Set Aside”)	Annual budget based on annual AIP appropriations and allocation formulas	Yes		69 - FY05-FY14 $184M ($146M federal & $38M airport match)	Standard AIP: 75% Large & Medium Hub Airports 90% Small & Non-Hub Airports
Airport Energy Efficiency Program (Section 512)	Entitlements and Discretionary (No “Noise & Environmental Set Aside” funds)	As justified	No	EEP provides added justification or “trigger” for grants	4 – FY12-FY14	Standard AIP: 75% Large & Medium Hub Airports 90% Small & Non-Hub Airports
Airport Sustainability Plans	Entitlements and Discretionary (No “Noise & Environmental Set Aside” funds)	As justified	No		44 – FY09-FY14	Standard AIP: 75% Large & Medium Hub Airports 90% Small & Non-Hub Airports
Zero Emissions Vehicle and Infrastructure Pilot Program	Entitlements and Discretionary (primarily “Noise & Environmental Set Aside”)	As justified	No	Ends after FY 2015	1 - FY 2013	50%
Airport Improvement Program (AIP) & Passenger Facility Charge Program (PFC)	Entitlements and Discretionary	Annual appropriation	Yes		Information available on AIP and PFC web sites	Standard AIP: 75% Large & Medium Hub Airports 90% Small & Non-Hub Airports

APPENDIX D

State Renewable Energy Programs—Example of North Carolina

North Carolina has become one of the most attractive states in the nation for investing in renewable energy generation, including solar, wind, hydro, and geothermal systems. As an example, in 2013 North Carolina installed 335 MW of solar electric capacity, ranking it 3rd nationally.[1] State incentives available to non-government and government entities are described below.

Incentives Available to Non-Government Entities

Complementing a 30% federal tax credit for renewable energy investments, North Carolina offers a 35% tax rebate to taxpayers who construct, purchase, or lease an eligible renewable energy system. The annual state tax credit is available for residential applications up to $10,500, depending on the technology, and up to $2.5 million for commercial and industrial facilities for solar, wind, hydro, and biomass projects.

The state tax credit has made a critical difference to the economics of renewable energy development and has attracted growing interest among third-party investors and energy management companies. On solar installations, for example, the allowable investment tax credits for solar energy range from a maximum of $1,400 for solar hot water heating systems, to $3,500 for active and passive space heating systems, and $10,500 for PV solar electric systems. Since most airports are owned by government entities and do not pay taxes, they are not eligible for federal/state tax credits. However, these incentives can be used by a third-party contractor to develop a renewable energy project at an airport and thereby share the benefit of such arrangement through a long-term PPA.

Incentives Available to Government Entities

For organizations not eligible for the federal/state tax incentives but still looking to develop a renewable energy project, there are incentives offered in North Carolina through independent nonprofit organizations, utilities and the Tennessee Valley Authority (TVA).[2]

- The NC GreenPower Production Incentive offers payments per kWh to producers of electricity from solar, wind, biomass, and small hydropower (<10 MW). NC GreenPower is an independent nonprofit that issues RFPs from time to time based on consumer demand for renewable electricity in the state. Owners of small PV (<5kW) and wind (<10kW) can

[1] Solar Energy Industry Association.
[2] Energy.Gov Office of Energy Efficiency and Renewable Energy, Updated April 2013.

apply anytime. Reimbursement rates vary by technology and time depending on the bidding process.

- Duke Energy's Standard Purchase Offer for RECs reimburses owners of renewable energy generation systems located in Duke's service territory for the value of RECs generated. Prices are $20 per RECs from solar (i.e., SRECs) with a minimum production of 35 MWh/yr, and $5 per REC from other renewable energy systems for a minimum of 50 MWh. Contracts can range between 5 and 15 years.
- To encourage the development of small scale wind, biomass, solar and hydro, the TVA through its Green Providers Program will purchase the electric output from systems rated at 50 kW or less for twenty years. Reimbursement rates are $0.09 per kWh for solar above the retail rate and $0.03 per kWh above the retail rate for other renewable systems. As part of the program, the TVA retains all rights to the RECs.
- For larger projects, the TVA will purchase electric output for projects greater than 50 kW and up to 20 MW from developers of biomass combustion, biomass gasification, methane recovery, wind, and solar systems. Reimbursement averages 5.5 cents per kWh. There are additional conditions the developer must meet including but not limited to the TVA retaining the rights to the RECs as well as maximum production limits and conditions associated with financing and interconnection agreements.

Renewable Energy Portfolio Standard

Another factor propelling renewable energy development in the state is its Renewable Energy Portfolio Standard. Under the 2007 standard, all electric power suppliers in North Carolina must supply a growing percentage of their retail customers' future energy demand by a combination of renewable energy resources and reduced energy consumption. The standard began at 3% of retail electricity sales in 2012, and rises to 10% of retail sales beginning in 2018 for the state's electric membership cooperatives and municipally owned electric providers and 12.5% of retail sales beginning in 2021 for the state's electric public utilities.

North Carolina is embracing the economic opportunities provided by the renewable energy industry, including the permanent well-paying jobs it creates. In 2013, North Carolina claimed to be the fifth largest solar market in the United States, supporting over 15,000 direct jobs and more than 1,100 companies in the clean energy sector. The organizational hub of state efforts to promote renewable energy is the 25-year old North Carolina Solar Center (NCSC), located at North Carolina State University in Raleigh. The Center, which is financed partly through state appropriations, has evolved beyond its historic focus on solar energy to encompass many types of renewable energy and clean technology. The Center provides a range of support services such as training workshops and classes, technical assistance, public education, and fee-based project assessments.

In the area of technical assistance, NCSC issued a 28-page guide for solar developers in December 2013 that contains specific information on current state regulations and permit requirements. The report, "Template Solar Energy Development Ordinance for North Carolina," covers common considerations in siting a solar facility, including setback requirements, height limitations, visibility and buffering requirements, and decommissioning plans. The report also includes a specific section on aviation notification requirements, which vary depending on the proximity of the proposed site to an airport, and the potential for an ocular impact (glare or glint) on pilots or air traffic controllers.

North Carolina has a longstanding reputation for research and development of emerging new industries and technologies. Fostering the renewable energy industry is part of the state's general economic development strategy, and it is paying off in the rapid growth of solar energy and other renewable energy systems throughout the state.

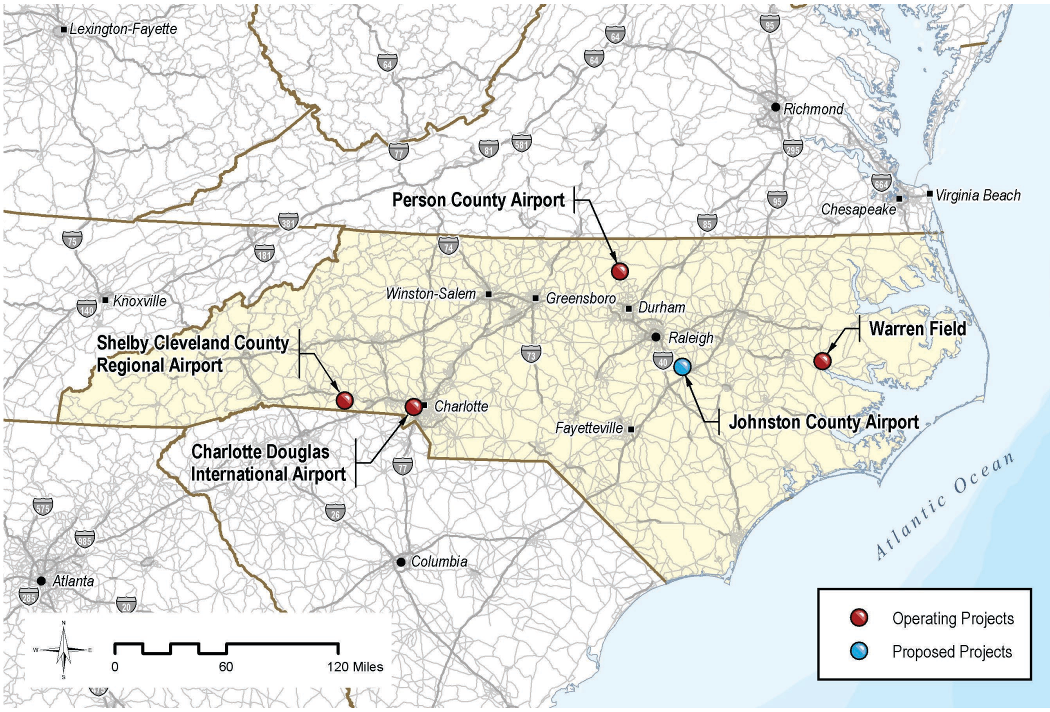


Figure D-1. Solar projects at airports in North Carolina.

Renewable Energy at Airports

Several airports in North Carolina operate solar systems or lease airport land that is not needed for aviation purposes to third-party solar developers. Figure D-1 shows the location of solar projects operating at airports and those known to be under development.

The largest solar enterprise in the state is Duke Energy Renewables, a part of Duke Energy's Office of Commercial Business. The company owns or operates about 1,700 megawatts (MW) of renewable energy, most of it generated by wind power, based on a reported $3 billion in related investments throughout the United States since 2007. Two of Duke Energy's PV solar projects in North Carolina include airport facilities at Shelby Municipal Airport (EHO), owned by the city of Shelby, and Warren Field Airport (OCW), owned by the city of Washington. The Shelby project began operating in 2010 and is a 1 MW system consisting of 4,522 ground-mounted panels on a 10-acre site. The Warren Field project began in 2013 and is a 5 MW system comprising 23,000 PV modules. In the case of Warren Field, the airport earns a lease payment of $1,200 per acre per year. With 35.9 acres under lease, the lease payment provides the airport with $43,080 in revenue annually.

Charlotte-Douglas (CLT), the largest airport in North Carolina with over 18 million annual enplanements, built a 235 kW PV solar system mounted on the roof of the CLT Center, the main administration building for airport operations and employees. The system was fully funded and installed by a third-party company, which received the tax and investment benefits. The airport has a 20-year lease on the system, with an option to buy the system in designated years 6, 10, 15, or 20 at its depreciated value. The developer is also receiving revenue from the sale of the system's RECs to Duke Energy for purposes of meeting the utility's state energy portfolio requirements for renewable energy.

In 2014, CLT had planned to build an enormous 53 MW system, spanning 128 acres of ground between runways, building roofs, and parking lots, but it was deferred due to potential issues with the airport master plan and potential conflicts with CLT tax-exempt bonds for airport parking lot projects.

APPENDIX E

Solar Feasibility Assessment—Monterey Regional Airport

MONTEREY REGIONAL AIRPORT

Solar Feasibility Study

Fly MONTEREY

TABLE OF CONTENTS

MONTEREY REGIONAL AIRPORT – SOLAR FEASIBILITY STUDY

Fly MONTEREY

EXECUTIVE SUMMARY

As part of ACRP 01-24, "Renewable Energy as an Airport Revenue Source", we assessed the potential of a solar installation at Monterey Regional Airport and conducted an economic assessment to demonstrate the financial benefit of on-site solar generation. In our analysis we estimated the economic value of solar under different tariff structures and evaluated anticipated savings under different financing options.

We looked at building roof-mounted systems, carports and ground-mounted systems at the airport. The analysis is based on existing conditions. We understand that a new terminal building and new parking lots are being considered as part of the airport master plan. The information that we present below for the existing terminal building could be used in planning for on-site solar generation in conjunction with future development.

Our analysis shows that the airport can maximize savings through a cash purchase, under the assumption that it can access FAA grants and issue tax exempt revenue bonds. The second best scenario is a Power Purchase Agreement (PPA) with an Early Buyout option, through which the airport can optimize the financing cost, as i) it can access, indirectly, the federal tax benefits[1], which are available only to private tax equity investors and ii) can use low cost tax-exempt financing to purchase the system in Year 6.

Location availability and suitability will determine the rate tariff, under which the airport will be able to receive bill credit for the solar installation. As our analysis shows the optimal tariff structure would be Net Energy Metering (NEM), which would require a rooftop and carport installation at the terminal building.

The table below provides a summary of the expected savings under different tariff and financing options:

Financing Method		Tariff Option	
		NEM Tariff	RES-BCT Tariff[2]
Cash Purchase – Self Ownership**	30-year Total Net Savings	$5,636,293	$3,277,844
	NPV of Savings*	$2,330,482	$1,309,949
PPA with Early Buy Out Option***	30-year Total Net Savings	$5,157,871	$3,044,973
	NPV of Savings	$2,083,535	$1,190,685
PPA with Early Buy Out Option	30-year Total Net Savings	$3,593,141	$1,977,746
	NPV of Savings	$1,355,975	$694,452
PPA	25-year Total Net Savings	$1,260,433	$361,154
	NPV of Savings*	$663,965	$190,247

*5% Discount Rate used for Net Present Value analysis
**Assuming FAA funding will cover 50% of the project cost
***50% of the Buyout value is funded with an FAA grant

[1] 30% Investment Tax Credit
[2] Renewable Energy Self-Generation Bill Credit Transfer

SITE ASSESSMENT

We completed a high level site assessment of Monterey Regional Airport's main locations to identify areas that are suitable for rooftop, carport and ground solar systems. Our goal is to optimize the overall cost of the solar system, by selecting areas that are either close to the desired meter location or allow for a ground installation. The table below provides a summary of the identified locations and the potential capacity in each location.

SITE	TOTAL USABLE AREA (ft^2)	PRODUCT TYPE	MODULE TYPE	WATTS/FT^2	POTENTIAL CAPACITY (kWdc)
Terminal Building - Roof	10,800	Rooftop	High Efficiency Panels[3]	12.4	117
Terminal Building – Parking Lot 1	6,000	Carport	High Efficiency Panels	18.7	112
Terminal Building – Parking Lot 2	16,000	Carport	High Efficiency Panels	18.7	299
Terminal Building – Parking Lot 3	4,000	Carport	High Efficiency Panels	18.7	75
Northeast Ground Area	180,653	Ground Fixed Tilt	High Efficiency Panels	9.1	1,644

The terminal building meter is the largest meter on site, so we looked at all possible areas within or in proximity to the terminal building that could be used to install a solar system. The roof of the terminal building is approximately 18,000 square feet. However, due to required set-backs from the roof edge and some obstructions on the west side of the roof we estimated that about 11,000 square feet would be available for the solar installation. For a rooftop system in a new building, the set-back from the roof edge should be approximately 6 feet, while the set-back from the building for a carport structure should be approximately 20 feet. Assuming high efficiency solar panels, we estimate that the existing roof can accommodate a 117 kWdc system.

The parking lot at the west side of the terminal building can also be used to meet the additional capacity needed. Two single and one double cantilever canopies, nine feet high, tilted ten degrees to the south will provide an additional 486 kWdc.

In the event that the structural integrity of the roof or the underground soil conditions make the cost of a solar installation at the terminal building prohibitive, the airport can use the RESBCT tariff (explained in detail in the following section) to offset generation charges in all meters on site. Under this option, a ground installation at the flat area at the northeast side would optimize land usage and solar economics.

[3] Assumes 20% panel efficiency

MONTEREY REGIONAL AIRPORT – SOLAR FEASIBILITY STUDY

AERIAL VIEW OF IDENTIFIED LOCATIONS

ECONOMIC ASSESSMENT

For the economic assessment we took into account the following:

- Optimal tariff structure
- Array size based on annual energy demand and space constraints
- Utility bill savings as a result of the on-site solar generation
- Capital cost of the solar system, including pre-construction costs such as site preparation and permitting
- Post-construction costs such as operation and maintenance
- PV technology type, system configuration and energy output projections
- Electricity price inflation
- Available subsidies or incentives
- Available financing structures

TARIFF STRUCTURE

There are two tariffs under which the solar developer could interconnect the solar system at Monterey Regional Airport:

Net Energy Metering (NEM): allows the airport to size the solar generation to meet the annual load at the terminal meter only and to receive the full bundled retail rate for generation that offsets that load[4]. In other words, with net energy metering, the airport receives credit for generation, distribution and transmission charges, which comprise the total energy charge per kWh.

Since the terminal meter represents 76% of the total airport load and 70% of the airport's total electricity cost, we optimize the solar economics by offsetting the electricity bill in this main terminal meter.

Renewable Energy Self-Generation Bill Credit Transfer (RES-BCT): allows a Local Government[5] or government entity to install up to 5 MW of renewable generation (generating account) within its geographic boundary, offset any coincident usage at the generator site, and convert excess electricity exported to the utility grid to credits that can be used to offset generation charges at one or more other meters (benefitting accounts) of the same Local Government or government entity. The generating account may or may not have electrical usage on it.

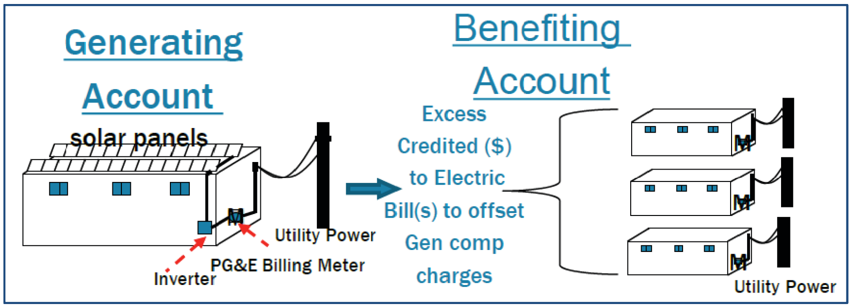
In the case of Monterey Regional Airport, PG&E will install a generating account meter close to the ground mount installation that separately measures both the electricity drawn from the utility grid and the energy that is exported to the grid. The metered exports to the grid are used to calculate the generation credits, which are allocated proportionally to the airport's 23 electric accounts. The

[4] http://www.cpuc.ca.gov/PUC/energy/DistGen/netmetering.htm

[5] Local Government is defined as a city, county, whether general law or chartered, city and county, special district, school district, political subdivision, or other local public agency, if authorized by law to generate electricity, but shall not mean a joint powers authority, the state or any agency or department of the state, other than an individual "Campus" (defined as an individual community college campus, individual California State University campus, or individual University of California campus)- of the University of California or the California State University.

generation credits are allocated so that they offset only the generation charges in the respective accounts. The generating charges represent roughly 50% of the total electricity bill cost.

The following chart illustrates the relationship between generating and benefiting accounts.



Given that under this tariff structure the airport can offset generation charges only and given that the terminal meter represents such a large percentage of the total load, a NEM interconnection is preferable. However, if, as mentioned earlier, the structural integrity of the roof or the underground soil conditions make the cost of a solar installation at the terminal building prohibitive, RES-BCT via a ground mount solution provide a viable alternative.

ARRAY SIZE

The Site Assessment we completed allows us to determine the solar capacity we can fit in each of the identified locations. In addition to the site assessment, proper sizing of the solar system requires thorough analysis of the electricity consumption on-site to ensure that the proposed solar array and expected energy production do not exceed the airport's energy needs. Both the total potential capacity and needed capacity are taken into account in determining the system size, as space limitations often determine the capacity the host (the airport in this case) can fit on its premises.

Monterey Regional Airport's load and available areas permit optimal sizing of the solar array as shown in the table below.

TARIFF	POTENTIAL CAPACITY (kWp)	CAPACITY NEEDED TO ZERO BILL/ OFFSET GENERATION CREDITS (kWp)	RECOMMENDED CAPACITY (kWp)
NEM	603	561	561
RES-BCT	2,113	442	442

ENERGY BILL SAVINGS ANALYSIS

As mentioned above a detailed energy bill analysis was conducted to determine the optimal system size based on the airport's load profile as well as the post solar rate schedule that will maximize the energy bill savings from the on-site solar generation.

NEM OPTION

The analysis was based on 12-month billing data from the main terminal meter (Meter # 0677R6) that were provided by Monterey Regional Airport. The billing data shows a total usage of 1.2 million kWh and an average electricity cost of $0.146/kWh, based on May 1st, 2014 PG&E rates.

Under the NEM option, we recommend that the airport switches the main terminal meter to PG&E's A-6 rate schedule, during the interconnection process. The service account is eligible for A-6, since the maximum demand at the terminal meter does not exceed 499kW. While regulatory changes may impact the availability of A-6 rate, we believe that timely project execution will enhance the airport's chances to secure this favorable rate schedule. The A-6 rate is maximizing the energy bill savings post-solar for the following reasons:

1. It has zero demand charges and higher energy charges.

2. It attributes a large monetary value to the Summer On-Peak hours, which are approximately $0.566/kWh. This is beneficial, as the Summer On-Peak hours (May 1 –Oct 31; 12pm-6pm) coincides with a period of time when the proposed solar system produces the most energy.

3. Under NEM, any billing credit generated during the Summer On-Peak hours goes toward offsetting billing debits incurred during Winter/Summer Part and Off-Peak hours, which are on average $0.154/kWh. This means 1 kWh of surplus production during the Summer On-Peak hour is worth about 3.6 times the monetary value of 1 kWh during the Winter/Summer Part/Off-Peak hours. This "arbitrage" results in a unique situation where the airport may offset a higher percentage of their electricity bill ($ value) relative to the energy offset (as measured in kWh).

The table below summarizes the energy bill before and after solar and the energy savings as a result of the solar project and the optimal rate structure.

TARIFF	METER #	ORIGINAL RATE SCHEDULE	PROPOSED RATE SCHEDULE AFTER SOLAR	ORIGINAL ENERGY USAGE (kWh)	SOLAR ENERGY PRODUCTION (kWh)[6]	% OF ENERGY OFFSET BY SOLAR	ORIGINAL ENERGY BILL ($)	ENERGY BILL AFTER SOLAR ($)	ANNUAL SAVINGS ($)	% OF ENERGY BILL OFFSET BY SOLAR	SAVINGS PER kWh ($/kWh)
NEM	0677R6	E-19S	A-6	1,200,443	884,082	74%	$174,987	$656	$174,330	99.6%	$0.197

RES-BCT OPTION

The analysis was based on 12-month billing data from the 23 active meters located on-site, as provided by Monterey Regional Airport. The billing data shows a total usage of 1.6 million kWh and total annual electricity cost of $218,535. Out of this, roughly 51% is generation charges and the rest is distribution and transmission charges. Thus the value of avoidable generation charges through RES-BCT would be approximately $111,000.

Through optimization of the RES-BCT rate structure, a 442kWp system producing about 740,000 kWh in the first year of operation will generate gross savings to the airport equivalent of $0.15/kWh, thereby

[6] Production estimates were made using PVSim, a proprietary PV simulation software

providing $111,000 of utility bill reduction and offsetting 100% of the generation component of the airport's total electricity bill.

The table below summarizes the utility bill savings under the RES-BCT option.

TARIFF	METER #	PROPOSED RATE SCHEDULE AFTER SOLAR	ENERGY USAGE (kWh)	ENERGY BILL ($)	SOLAR ENERGY PRODUCTION (kWh)	SOLAR GENERATION CREDITS ($)	% OF ENERGY BILL OFFSET BY SOLAR	SAVINGS PER kWh ($/kWh)
RES-BCT	All meters	A-6	1,571,525	$218,535	740,035	$111,091	50.8%	$0.150

SOLAR SYSTEM COST

The table below summarizes the estimated cost of the solar system under each of the above mentioned options. The cost is preliminary and based on optimal assumptions on site and soil conditions.

TARIFF	LOCATION	SYSTEM TYPE	SYSTEM SIZE	ESTIMATED PRODUCTION	SYSTEM PRICE
NEM	Terminal Building	Rooftop & Carport	561	884,082	$2,300,000[7]
RES-BCT	Northeast Open Field	Ground Fixed Tilt	442	740,035	$1,700,000[8]

FINANCING OPTIONS

There are three financing options the airport could consider for this project:

i) Cash purchase (Self Ownership);

ii) Power Purchase Agreement (PPA; Third-Party Ownership); and

iii) PPA with Early Buyout (Hybrid of Self and Third-Party Ownership)

The table below summarizes the differences among these three options:

	CASH	PPA	PPA WITH EARLY BUYOUT
Solar System Owner	Airport	Investor	Investor for the first 5 years; Airport thereafter
Payments	Upfront	Monthly, Variable	In Year 6 of the PPA term
Payment Basis	Negotiated Construction Milestones	Energy Production	Energy Production for the first 5 years; The higher of negotiated Early Buyout Value or Fair Market Value in Year 6
Term	System Useful Life (usually up to 30-35 years)	25 years	System Useful Life (usually up to 30-35 years)
Tax Incentive Owner	N/A	Investor	Investor
REC Owner	Airport	Negotiated	Negotiated

[7] This is based on an estimated average system price of $4.10/W, for a 120kWdc rooftop system and a 441kWdc carport system, assuming optimal site and soil conditions

[8] This is based on an estimated average system price of $3.84/W for a 442kWdc ground fixed tilt system, assuming optimal site and soil conditions. Costs related to environmental permitting, such as CEQA, are excluded.

CASH PURCHASE – SELF OWNERSHIP

Under self-ownership the airport and its financial advisor would identify the most cost-efficient source of financing to fund the solar system. The airport, as the owner of the system, is responsible for operation and maintenance and takes production risk, or the potential losses or gains from underproduction or overproduction. Moreover, upon full debt repayment, the airport is entitled to all potential energy savings realized through the solar project until the end of the system's useful life.

Financing the cost of the solar installation can be achieved through a combination of FAA Airport Improvement Program funds and Tax Exempt Revenue Bonds or Tax Exempt Lease Financing. The table below provides a summary of the expected 1st year and 30-year nominal savings as well as the project's expected net present value under different FAA funding scenarios.

NEM Option

Expected FAA Funding	50% of project cost	75% of project cost	90% of project cost*
1st Year Net Nominal Savings	$72,079	$118,219	$145,902
5-Year Net Cumulative Savings	$406,451	$637,148	$775,567
10-Year Net Cumulative Savings	$937,849	$1,399,244	$1,676,080
30-year Net Cumulative Savings	$5,636,293	$6,559,083	$7,112,757
Net Present Value of Savings**	$2,330,482	$2,905,482	$3,250,482

*Under the current Airport Improvement Program (AIP), Monterey Airport would be eligible for an FAA grant up to 90% of the project cost
**5% Discount Rate used for Net Present Value analysis

RES-BCT Option

Expected FAA Funding	50% of project cost	75% of project cost	90% of project cost*
1st Year Net Nominal Savings	$33,885	$67,988	$88,450
5-Year Net Cumulative Savings	$197,956	$368,471	$470,780
10-Year Net Cumulative Savings	$473,297	$814,328	$1,018,947
30-year Net Cumulative Savings	$3,277,844	$3,959,906	$4,369,143
Net Present Value of Savings**	$1,309,949	$1,734,949	$1,989,949

*Under the current Airport Improvement Program (AIP), Monterey Airport would be eligible for an FAA grant up to 90% of the project cost
**5% Discount Rate used for Net Present Value analysis

The savings presented above are based on the following assumptions:

	NEM Option	RES-BCT Option
System Size (kWdc)	561	422
Energy Yield (kWh/kWdc)	1,577	1,674
Utility Bill Savings per kWh	$0.197	$0.150
Utility Price Inflation	3%	3%
Solar Energy Degradation Rate	0.25%	0.25%
O&M Cost – Year 1	$10,000	$9,000
O&M Cost Escalation	3%	3%
Revenue Bond Interest Rate	5%	5%
Revenue Bond Term	20	20

Under this option the airport would own the Renewable Energy Credits (RECs) generated by the system. Currently there is no value for RECs generated in California. The above analysis has not accounted for any REC value, so if there is any value for the RECs in the future this will be an upside for the airport.

POWER PURCHASE AGREEMENT – THIRD-PARTY OWNERSHIP

Under third-party ownership the solar project is owned by a third-party, usually a tax-equity investor. The airport's sole responsibility is to pay for the energy generated by the system, at the rate negotiated in the Power Purchase Agreement (PPA). The investor funds the construction costs of the project, which allows him to utilize the federal Investment Tax Credits (ITC)[9] and accelerated depreciation (5-yr MACRS). Over the life of the contract, the investor also pays operation and maintenance fees. At the end of the PPA term, the airport has the option to purchase the system at fair market value or to request its removal. PPA terms vary between 20 and 25 years. For this project we have assumed a 25 year PPA contract. The table below provides a summary of the expected 1st year and 30-year nominal savings as well as the project's expected net present value under a PPA.

	NEM Option	RES-BCT Option
1st Year Net Nominal Savings	$35,756	$10,245
5-Year Net Cumulative Savings	$188,857	$54,113
10-Year Net Cumulative Savings	$405,070	$116,066
25-year Net Cumulative Savings	$1,260,433	$361,154
Net Present Value of Savings*	$663,965	$190,247

*5% Discount Rate used for Net Present Value analysis

The savings presented above are based on the following assumptions:

	NEM Option	RES-BCT Option
System Size (kWdc)	561	422
Energy Yield (kWh/kWdc)	1,577	1,674
Utility Bill Savings per kWh	$0.197	$0.150
Utility Price Inflation	3%	3%
Solar Energy Degradation Rate	0.25%	0.25%
PPA Rate	$0.157	$0.136
PPA Rate Escalation	3%	3%

Under this option the third-party system owner would own the Renewable Energy Credits (RECs) generated by the system. Currently there is no value for RECs generated in California. The above analysis has not accounted for any REC value.

The difference between the above stated PPA rates is driven by the difference in the cost of the two systems. The NEM Option, as mentioned earlier in this report, assumes a rooftop and carport system close to the Terminal Building. These structures are more expensive than the ground mount structure. Under each of the above tariff options we have selected the product type that would allow the airport to achieve up to 20% annual electricity bill savings.

[9] This analysis is based on the assumption that the project will be operational by the end of 2016 and investors will be eligible for 30% ITC. Based on the current regulatory framework, ITC is expected to drop from 30% to 10% starting January 2017.

PPA with EARLY BUYOUT – HYBRID SELF AND THIRD-PARTY OWNERSHIP

A PPA contract gives the option to the energy off-taker to purchase the system at two times during the contract term: One usually after Year 6, when the investor has monetized all the federal tax benefits, including the 5-yr MACRS, and one at the end of the PPA term. The public entity can use low cost tax-exempt financing to purchase the balance of the system cost after Year 6 and resume ownership of the project. The system purchase price at Year 6 will be the higher of the Fair Market Value or the pre-negotiated Early Buyout Value, as specified in the PPA contract. Under such structure the airport is able to optimize the financing cost, as it accesses, indirectly, the federal tax benefits, which are available only to private tax equity investors. The table below provides a summary of the expected 1st year and 30-year nominal savings as well as the project's expected net present value under a PPA with Early Buyout. We have included also a scenario, under which the airport could use the FAA grant to fund portion of the buyout value.

	NEM Option		RES-BCT Option	
	Buyout Funded with Tax Exempt Financing	50% of Buyout Funded with FAA Grant	Buyout Funded with Tax Exempt Financing	50% of Buyout Funded with FAA Grant
1st Year Net Nominal Savings	$35,756	$35,756	$10,245	$10,245
5-Year Net Cumulative Savings	$188,857	$188,857	$54,113	$54,113
10-Year Net Cumulative Savings	$416,788	$729,734	$145,882	$359,327
30-year Net Cumulative Savings	$3,593,141	$5,157,871	$1,977,746	$3,044,973
Net Present Value of Savings*	$1,355,975	$2,083,535	$694,452	$1,190,685

*5% Discount Rate used for Net Present Value analysis

The savings presented above are based on the following assumptions:

	NEM Option	RES-BCT Option
System Size (kWdc)	561	422
Energy Yield (kWh/kWdc)	1,577	1,674
Utility Bill Savings per kWh	$0.197	$0.150
Utility Price Inflation	3%	3%
Solar Energy Degradation Rate	0.25%	0.25%
PPA Rate	$0.157	$0.136
PPA Rate Escalation	3%	3%
O&M Cost – Year 6	$10,000	$9,000
O&M Cost Escalation	3%	3%
Estimated Buyout Value	$1,950,000	$1,330,000
Revenue Bond Interest Rate	5%	5%
Revenue Bond Term	20	20

Under this option the third-party system owner would own the Renewable Energy Credits (RECs) generated by the system during the first six years and the airport would own the RECs thereafter. Currently there is no value for RECs generated in California. The above analysis has not accounted for any REC value.

CONCLUSION

Based on the above analysis we conclude that the Terminal Building and the nearby parking lot as well as the ground area in the northeast side of the airport provide viable sites for solar generation.

Upon completion of the site assessment we evaluated two different tariff options that provide different benefits: The NEM tariff that allows full bill credit in a single meter and the RES-BCT tariff that allows offset of generation charges in all accounts on site. Under the NEM option we sized the array to 561kWdc based on the usage on the Terminal meter, and under the RES-BCT option we sized the array to 442kWdc based on the total generation usage in all airport meters. Our analysis shows that the NEM tariff is more cost effective, primarily due to the higher utility bill savings, driven by full bill credit and the A-6 rate structure. Utility bill savings are $174,330 under NEM versus $111,091 under RES-BCT.

Following our analysis on the economic value of solar we looked at different financing options to fund the capital cost of the system. Financing options depend primarily on opportunity associated with an FAA grant, which could result in a 4 to 7 year payback for the NEM system and a 4 to 8 year payback for the RES-BCT system. Alternatively, the airport could consider a PPA, which would result in up to 20% discount in the airport's utility bills and requires no up-front capital investment. At the end of year six the airport has the option to purchase the system at the remaining fair market value, and reap the long-term benefits of on-site solar generation.

APPENDIX F

Sample RFPs

Appendix F is not published here but is available on the TRB website at www.trb.org/Main/Blurbs/172634.aspx.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
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	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
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
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

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org

ISBN 978-0-309-30884-7
90000
9 780309 308847

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

ADDRESS SERVICE REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
COLUMBIA, MD
PERMIT NO. 88