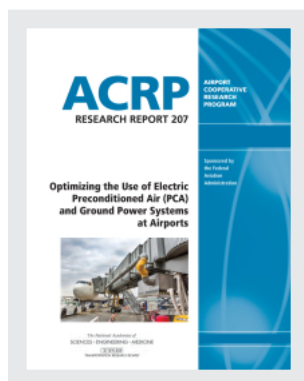


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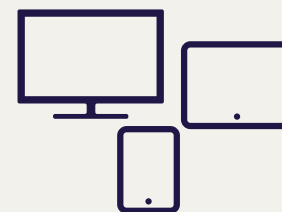
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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 207

**Optimizing the Use of Electric
Preconditioned Air (PCA)
and Ground Power Systems
at Airports**

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2019

AIRPORT COOPERATIVE RESEARCH PROGRAM

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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). ACRP carries out applied research on problems that are shared by airport operating agencies and not being adequately addressed by existing federal research programs. ACRP is modeled after the successful National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). ACRP undertakes research and other technical activities in various airport subject areas, including design, construction, legal, maintenance, operations, safety, policy, planning, human resources, and administration. ACRP provides a forum where airport operators can cooperatively address common operational problems.

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

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Cover photo: Aircraft connected to PCA and ground power.

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(continued on page vi)



FOREWORD

By Theresia H. Schatz

Staff Officer

Transportation Research Board

ACRP Research Report 207 provides guidance in identifying and understanding factors that contribute to the use or non-use of gate electrification systems [electric preconditioned air (PCA) and electric ground power systems] and ways that airports and airlines can optimize the use of the systems.

As demand for air travel grows, airport-related emissions are increasing and airports are challenged to reduce associated environmental impacts. In response, expanded regulatory programs and global climate protection initiatives are being developed that require the aviation industry—including U.S. airports—to implement new, clean technologies and to modify operational practices to reduce emissions. One effective option for reducing the emissions associated with aircraft auxiliary power units (APUs) and diesel-powered gate equipment is to convert to electric PCA and electric ground power systems, collectively referred to as “gate electrification systems.”

Through the Voluntary Airport Low Emissions (VALE) Program, the FAA enables airports located in areas that do not meet EPA air quality standards to meet their air quality responsibilities under the Clean Air Act. The VALE program reduces air emissions through projects such as gate electrification at airports located in areas designated as “nonattainment” or “maintenance” to address air quality concerns from criteria pollutants, such as ozone or PM 2.5. Many airports and airlines have supported these initiatives in light of the environmental, operational, economic, and other social benefits associated with reduced run times of APUs. Although these systems are installed at many airports, and airline staff interviewed for this project have implemented strategic initiatives to maximize equipment utilization, gate electrification systems may not be fully utilized for a variety of reasons.

This research, led by Harris Miller Miller & Hanson, Inc. (HMMH) in association with James M. Crites, LLC, and Barrett Energy Resources Group, LLC, includes case studies at a variety of types and sizes of airports in different climates; an evaluation of how weather and climate impact utilization; the use and impact of other available ground power and PCA units; consideration of aircraft hardstand operations; and airport and airline practices for optimal equipment utilization. Stakeholders consulted throughout the project include airports, airlines, pilots, equipment manufacturers, service providers, and industry associations. Outreach took the form of in-person focus groups, meetings, telephone interviews, and online surveys. The report also includes a self-assessment checklist and basic utilization tracking methodology, available on www.trb.org by searching for “ACRP Research Report 207.” These tools provide industry stakeholders with a simple approach to obtain this information in the future.

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SUMMARY

Optimizing the Use of Electric Preconditioned Air (PCA) and Ground Power Systems at Airports

The principal objective of ACRP Project 02-76 is “to provide guidance in identifying and understanding factors that contribute to the use or non-use of gate electrification systems (electric preconditioned air and electric ground power systems) and ways that airports and airlines can optimize the use of the systems” (ACRP Project 02-76 Request for Proposal). The objective was achieved through engagement with a range of stakeholders, including airport staff from environmental, operational, maintenance, and finance departments; airline staff; airline pilots; and preconditioned air (PCA) and ground power equipment manufacturers and service providers. The airports interviewed and surveyed for this project represent a range of sizes, geographic locations, and climate zones.

This report is based on information gathered from stakeholders through in-person focus groups, case study interviews, and online survey instruments, supplemented by the literature review. The research considered the impact of weather and climate on utilization, as well as common utilization tracking practices, airport and airline policies with regard to utilization, best practices for maintaining system availability, and motivating factors affecting the acquisition of systems.

This report was developed for all stakeholders involved in the acquisition, installation, operation, maintenance, and utilization of electric PCA and ground power systems. The contents of the report are organized into six chapters:

1. Introduction—This chapter provides background information and establishes the need for the research project, as well as the research approach.
2. Ground Power and Air Conditioning Systems—This chapter provides an overview of commercial aircraft power needs, gate electrification equipment, and systems.
3. Challenges Affecting Gate Electrification System Utilization—The most common challenges to gate electrification system utilization are described in this chapter, which also includes a description of the Self-Assessment Checklist. The checklist is intended to assist stakeholders in identifying challenges to utilization at their specific locations.
4. Solutions to Address Utilization Challenges—Proposed solutions to address common challenges are described in this chapter.
5. Utilization Tracking Methodology—This chapter describes a basic example of utilization tracking methodology designed for airports to deploy without significant resource investment.
6. Airport Case Studies—Fifteen case studies from airports across the U.S. (and one in Europe) are included to provide readers with an understanding of various types and configurations of gate electrification systems, ownership and maintenance models, and best practices for ensuring system reliability.

2 Optimizing the Use of Electric Preconditioned Air (PCA) and Ground Power Systems at Airports

The report also contains additional information in the appendices, including a summary of responses to the airport and pilot surveys. The Airport Self-Assessment Checklist and example Utilization Tracking Methodology are provided as separate Excel files for download.

CHAPTER 1

Introduction

Air quality presents a multifaceted issue of concern to airports, their surrounding communities, and other stakeholders, in the U.S. and globally. Airport and airline operations result in the emission of various air pollutants from numerous sources, including aircraft engines, ground support equipment, passenger and employee vehicles, rental cars, shuttle buses, ground vehicles in general, and generators. EPA regulates the emission of six criteria air pollutants—ozone (O_3), particulate matter (PM), lead (Pb), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2)—determined to have adverse impacts on human health and welfare. The emission of these criteria pollutants, through activities that involve burning fossil fuels, are regulated under the Clean Air Act.

In addition to concerns about local air quality, the aviation industry acknowledges its contribution to global climate change through the emission of carbon dioxide (CO_2) and other greenhouse gases from the combustion of fossil fuels (Air Transport Action Group 2018). While there are no federal regulations requiring U.S. airports to limit or reduce their greenhouse gas emissions, there are some reporting requirements at the federal and state levels (see Code of Federal Regulations [Environmental Protection Agency 2009] and California Code of Regulations [California Air Resources Board 2009]). Many airports are taking proactive steps to address these impacts and better manage their carbon footprints. Other countries are also implementing restrictions on greenhouse gas emissions, and the International Civil Aviation Organization (ICAO) has developed the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) in an attempt to reduce the carbon footprint from international aviation. Airlines are taking steps to reduce greenhouse gases from their operations, as well. Their efforts include developing and promoting sustainable aviation biofuels through the Commercial Aviation Alternative Fuels Initiative and setting industrywide climate targets and greenhouse gas emissions reduction goals (Air Transport Action Group 2018).

Airlines have incentive to reduce their emissions for both regulatory and economic reasons. Fuel is one of the largest costs to an airline. Reducing fuel use reduces costs and produces fewer emissions. Regulatory requirements, airport policies and goals, economics, community concerns, and other factors combine to form a strong motivation for airports and airlines to examine all opportunities to reduce air-pollutant emissions from their operations.

One way in which airports have facilitated the reduction of emissions from operations is the installation of electric ground power and PCA, collectively referred to as gate electrification systems. These systems provide cleaner power for aircraft while parked at the gate, as opposed to aircraft using jet fuel-powered, auxiliary power units or mobile, diesel-powered, ground support equipment.

The acquisition and installation of gate electrification equipment represents a significant investment, with great potential for both economic and environmental benefits. On-site

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challenges, which prevent these systems from being utilized to the maximum extent possible, frequently occur at airports. This project sought to identify those barriers and impediments to use, as well as to establish a common methodology for tracking utilization over time to help industry stakeholders improve performance and realize the potential economic and environmental benefits of use.

The objective of this report and accompanying products—the Utilization Tracking Methodology and the Self-Assessment Checklist—is to assist airports and airlines with identifying and understanding the factors that contribute to the use or non-use of gate electrification systems and the potential solutions to improve system optimization.

1.1 Background

As airports seek to manage and reduce air emissions of criteria pollutants and greenhouse gases, they often examine both direct (airport-owned) and indirect (non-airport-owned) emissions sources to identify improvement opportunities. Airports directly control emissions sources such as airport-owned vehicle fleets, generators, electricity consumption in buildings, and corporate travel. With regard to indirect sources controlled by tenants, the most significant source of both criteria pollutant and greenhouse gas emissions is aircraft. Airports and airlines have been working to further reduce emission of criteria air pollutants and greenhouse gases through the installation of gate electrification systems, which allow aircraft to supply their power needs from airport-provided electricity while parked at the gates.

Aircraft are powered by their main engines during flight but require energy to power onboard systems and provide cabin heating and cooling while on the ground. Aircraft are equipped with auxiliary power units (APUs) not only to provide the power necessary to start the main aircraft engines (the APU's primary purpose) but also to supply onboard power continuously to support aircraft electronic systems and cabin conditions. Like main aircraft engines, APUs are gas turbine engines powered by jet fuel and, as a result, emit air-pollutant emissions and greenhouse gases.

Gate electrification systems can minimize aircraft use of APUs and related emissions. These systems include heating, ventilation, and air conditioning (HVAC) capabilities—referred to as PCA—and ground power (400 Hz or 28-volt direct current). PCA and ground power systems are often both installed on jet bridges to provide gate electrification. By using electricity from the airport instead of the jet fuel-powered APU, airlines can reduce criteria pollutants and greenhouse gas emissions. Airports can likewise reduce the emission of these pollutants on site. While providing electricity to PCA and ground power equipment still results in emissions (from the power plant supplying the electricity), the amount of emissions is often lower than that produced by APUs or diesel-powered mobile units due to fuel types used in power-generating facilities and local emissions factors (i.e., natural gas versus jet fuel or diesel). Presumably, there are other efficiencies in the use of building-fed systems, and some portion of the electrical supply may be fed from grids connected to clean energy sources.

Airports have worked in collaboration with FAA, airlines, and other stakeholders to obtain funding and garner support for the acquisition and installation of gate electrification systems. Utilizing and maintaining these systems require a collaborative effort between many airport stakeholders. Although the air quality benefits of using electric ground power and PCA instead of APUs are well understood, these systems are not always fully utilized.

This report includes background information on the basic components of gate electrification systems and equipment (Chapter 2), challenges affecting gate electrification system utilization and a self-assessment tool for identifying challenges (Chapter 3), practical solutions

to address utilization challenges (Chapter 4), and a common Utilization Tracking Methodology (Chapter 5). Finally, Chapter 6 includes several case studies to provide insight into gate electrification system configuration, acquisition and installation factors, maintenance best practices, and other insights at airports of various sizes and climates.

1.1.1 Environmental and Regulatory Context

Ensuring that their operations do not place an unacceptable burden on the environment is a priority for airports, often including a strong focus on local air quality. During this research, several airports reported that their neighboring communities showed interest and awareness with regard to the potential impacts of airport operations on local air quality and public health. In addition to addressing community concerns, airports are subject to federal and state regulations with regard to air quality. Regulatory considerations may motivate airports to seek opportunities to reduce emissions of air pollutants from all sources at the airport, including from ground operations.

Federal Clean Air Act

Under the Clean Air Act, EPA regulates the concentration of six air pollutants determined to have adverse impacts on human health and welfare. These six criteria pollutants are CO, Pb, NO₂, O₃, PM, and SO₂. These pollutants are emitted from burning fossil fuels, including from the operation of vehicles and aircraft.

EPA sets standards for acceptable concentrations of each criteria pollutant through the National Ambient Air Quality Standards (NAAQS). The NAAQS are determined through vigorous research and set the limits for each of these pollutants—known as primary standards—necessary to protect public health. They also set the levels necessary to protect public welfare (i.e., negative impacts on soils, buildings, animals, visibility, crops, and so on), known as secondary standards (Environmental Protection Agency 2017).

Areas that exceed the limits set by the primary and secondary NAAQS for each criteria pollutant are designated as nonattainment areas; conversely, areas that meet all primary and secondary standards are considered in attainment. Additionally, nonattainment areas are further classified into several levels based on the level of exceedance of the NAAQS and listed from least to greatest exceedance (e.g., marginal, moderate, serious, severe, and extreme).

States with nonattainment areas for any of the six criteria pollutants must develop plans to reduce emissions levels for those pollutants to meet the national standards through state implementation plans. It is particularly important for those areas of the country that are in nonattainment—or maintenance areas (recently emerged from nonattainment)—to reduce the emissions of the designated air pollutants. FAA encourages airports located in nonattainment or maintenance areas to reduce pollutant emissions through the designated grant programs (described in Section 1.1.2).

National Environmental Policy Act

In addition to the air quality standards set forth in the Clean Air Act and NAAQS, the National Environmental Policy Act (NEPA)—enacted in 1970—requires the federal government to undertake environmental reviews of all major actions that have significant impacts on the environment. As a federal agency, FAA must evaluate and disclose the impacts of certain airport projects on the environment, including impacts on air quality (FAA 2015A). As a result, airports often must develop air emissions inventories for projects that require an environmental assessment or environmental impact statement, as per NEPA. Airports may also be subject to state or local air quality regulations and requirements beyond those required by the Clean Air Act and NEPA.

Climate Change Initiatives and Regulations

Airports are increasingly aware of their global impact with respect to climate change and are, thus, taking innovative steps to reduce their greenhouse gas emissions. While there are no federal regulations requiring airports in the U.S. to limit or reduce their CO₂ emissions, there are federal reporting requirements for facilities that emit 25,000 metric tons of carbon dioxide equivalent (CO₂e) or more on an annual basis (Environmental Protection Agency 2009).

Many airports that have taken steps to address their greenhouse gas emissions are doing so voluntarily. As of October 2018, for example, 39 airports in North America were participating at one of the four levels of the Airport Carbon Accreditation Program (Airport Carbon Accreditation 2018). To achieve accreditation for the last three levels, airports must have a plan in place to manage and reduce CO₂ emissions and must be able to demonstrate an average annual reduction in CO₂ emissions. Another significant component of the program at higher levels involves airport engagement with stakeholders and tenants to reduce non-airport-controlled emissions, such as those from APUs and mobile diesel-powered PCA and ground power units (Airports Council International–Europe 2018).

At the international level, the ICAO—of which the United States is a member—has implemented two resolutions to address greenhouse gases from international aviation. The first resolution—the Consolidated Statement of Continuing ICAO Policies and Practices Related to Environmental Protection: Climate Change (A37-19)—passed by the ICAO General Assembly in 2010, consisted of a high-level roadmap for greenhouse gas reductions and included language requesting member states to voluntarily develop state action plans to reduce greenhouse gases from international aviation (Tetra Tech EBA 2014). While this resolution does not require states to focus on reducing APU emissions, ICAO members and industry stakeholders have taken a comprehensive approach to emissions reductions. FAA developed the U.S. plan, which includes measures to reduce greenhouse gases from aviation (both domestic and international) by implementing more efficient airframe and engine technologies, carrying out more efficient operations, and advancing alternative (nonpetroleum-based) jet fuel (FAA 2012). The Canadian State Action Plan specifically includes language addressing emissions from APUs by promoting the use of electric PCA and ground power.

The second ICAO resolution—CORSIA (A39-3)—is designed to reduce emissions from international aviation through emission tracking and the purchase of carbon offsets. These initiatives support ICAO’s mid-term goal of carbon-neutral growth from 2020 (i.e., no growth in CO₂ emissions after a certain date). Again, while this resolution does not specifically target emissions from APUs, those emissions must be considered if the industry is to reach the ambitious carbon-neutral growth goal.

1.1.2 Economic Considerations

Airports and airlines interviewed for this project overwhelmingly agreed that the benefits of gate electrification systems, such as lower fuel and APU maintenance costs and air quality benefits, outweigh the costs of the equipment. Despite this broad agreement on the benefits, airports and airlines must consider the costs associated with the procurement, installation, operation, and maintenance of gate electrification systems during the planning process to ensure a sustainable investment.

The reduction in fuel costs associated with replacing aircraft APU use with gate electrification equipment is one example of an economic benefit to airlines. Furthermore, APUs are not designed for extensive use. Overuse of APUs results in increased maintenance and additional costs associated with having an aircraft out of service. Therefore, airlines also consider the cost savings associated with less-frequent APU maintenance—and, subsequently, less aircraft time out of service—when APU use is replaced by gate electrification systems.

A variety of funding mechanisms can be used to procure gate electrification equipment, as well as to cover costs associated with installation of the equipment and any utility infrastructure upgrades necessary for its operation. Airports and airlines fund the purchase and installation of gate electrification equipment through the following mechanisms or some combination of such mechanisms:

- **Airport Improvement Program (AIP) grants:** AIP is funded through taxes imposed on the purchase of aviation fuel and on fees paid by airlines. AIP funds are appropriated annually by Congress and can be distributed to airports for a variety of planning and development projects. (Project eligibility is described in detail in FAA Order 5100.38D, the *Airport Improvement Program Handbook*.)
- **Voluntary Airport Low Emissions (VALE) program grants:** The VALE program is designed for airports that are located in EPA-designated nonattainment or maintenance areas (see Section 1.1.1.). VALE grants are awarded on a competitive basis to eligible airports based on funding availability and other factors, including anticipated emissions savings and cost effectiveness. Eligible project types for VALE funding include alternative fuel vehicles, gate electrification (PCA and ground power), remote ground power (for remain-overnight remote parking positions), and electric or alternative-fueled ground support equipment. As of September 2018, the FAA VALE program has funded 54 projects related to gate electrification (PCA and/or ground power installations) at 39 airports. These 54 projects make up more than half of the 105 VALE grants made at this time to 51 airports, making gate electrification the most common type of VALE project implemented by a majority of the airports (FAA 2018).

The collection of case studies in Chapter 6 of this report includes examples of airports that have used VALE grants to acquire this equipment, as well as those that have used other means.

- **Passenger facility charge revenue:** Passenger facility charges are fees imposed by airports per enplaned passenger. Use of these funds requires FAA approval before expenditure. Eligible projects include those that improve the safety, security, and capacity of the air transportation system; increase competition among air carriers; or reduce and/or mitigate noise.
- **Airport rates and charges:** Airport rates and charges are fees assessed on aeronautical users of the airport.
- **Airline investments:** At some airports, airlines own gates (or have owned them in the past), have exclusive use leases for gates, and have funded the acquisition and installation of gate electrification systems.
- **Nonaeronautical revenue:** This category is defined as revenue generated from nonaeronautical activities at an airport, such as parking fees, concessions, ground transportation service provider fees, and so on.

This project included a review of funding mechanisms used by case study airports to determine if a correlation between system financing and utilization rates exists. The research did not find a link between these two variables, as there are not enough available data on utilization rates to determine if such a relationship exists. While airports that used VALE grants for PCA and/or ground power projects do have an obligation to track the use of the equipment to determine the reduction in air pollutant emissions, there was no comparative data set to determine if a correlation exists.

Due to the large investments by many stakeholders (including FAA, airports, and airlines), there is significant interest in determining if and how these systems are being used. The importance of quantifying return on investment, as well as impact on air quality, are two reasons why determining utilization of the systems is important.

There are resources available to airports to determine the costs and benefits of installing gate electrification systems. Two such resources are *ACRP Report 64: Handbook for Evaluating Emissions and Costs of APU's and Alternative Systems* (Environmental Science Associates 2012)

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and the Airports Council International–World Aircraft Ground Energy System–Simulator (AGES–S), which enables users to calculate the economic and environmental benefits of replacing the use of APUs with gate electrification systems at their airport. Outputs of the AGES–S tool are intended to provide customized information that can be used by airports seeking to develop a business case for investment in gate electrification systems (Airports Council International 2018). These tools are useful for determining the business case to install PCA and ground power equipment, but they do not provide methodology for determining utilization once the equipment has been installed.

1.2 Description of Research Approach

The research team’s approach to developing this report followed a task-by-task process, which involved reviewing existing research and references to ascertain the current state of understanding on challenges affecting airport gate electrification system utilization. The literature review was followed by an extensive stakeholder outreach process.

The multistakeholder engagement process was designed to identify and analyze the challenges and barriers to optimal utilization, as well as to document the practices that may increase utilization rates. As described in this section, the assembly of relevant stakeholders from airports and airlines yielded critical information for developing the report. By design, stakeholders encompassed a variety of parties—including airport environmental, operations, and maintenance staff; airline corporate representatives; pilots and station managers; service providers (e.g., ground handling companies and fixed-base operators); and equipment manufacturers—with differing motivations and priorities to obtain as many perspectives as possible.

As a platform to engage with these diverse stakeholder groups, the researchers conducted two in-person focus groups and 15 case studies via web-based interviews with U.S. airports and one airport in Zurich, Switzerland. The team also interviewed a variety of equipment manufacturers and additional industry stakeholders. To gather additional stakeholder insights, the focus groups and case study interviews were followed up with web-based surveys sent to both airports and airline pilots.

Based on the input received from the focus groups, case studies, and surveys, the most common challenges and barriers to optimal system utilization were identified, along with possible solutions to the challenges. In addition, an example Utilization Tracking Methodology was designed for airports to monitor gate electrification utilization. A self-assessment tool was also developed to provide airport and airline practitioners with a simple approach to identifying the factors that affect the use of gate electrification at their specific airports and determining solutions to address those challenges.

The various engagement methods and stakeholder groups are described in the following sections.

1.2.1 Focus Groups

The initial industry-engagement activities took the form of in-person focus group meetings held at Dallas–Fort Worth International Airport and Boston Logan International Airport. These meetings were structured to encourage open dialogue and participation from all attendees. Attendees included airport environmental, operations, planning, and maintenance staff, as well as airline personnel and service providers. The focus groups were intended to identify the challenges and barriers to PCA and ground power utilization, the root causes of each challenge, and potential solutions or best management practices to solve the problems identified.

Each focus group took place over several hours. The discussion included topics such as human factors, system and component design factors, training and communication, technology factors, maintenance factors, and climate impacts. The outcome of the focus groups was a baseline understanding of the factors affecting gate electrification system utilization that was used to develop the airport and pilot surveys, as well as to guide discussions in the subsequent case study interviews.

1.2.2 Case Studies

In addition to the in-person focus group meetings, the research project involved a series of web-based case study interviews with 13 airports. (Case studies were also prepared for the two focus group airports, for a total of 15 case studies). The case study airports were specifically selected to include a diverse range of airport sizes and geographic locations.

The intent of the airport case studies was to:

- Explain and demonstrate the factors involved in the decision to acquire and install gate electrification infrastructure;
- Identify the variables affecting utilization;
- Determine successful methods for stakeholder engagement and collaboration;
- Recognize financial considerations;
- Identify factors that inhibit deployment and use of gate electrification equipment, as well as opportunities to overcome these factors; and
- Represent a range of airports with regard to VALE status and the extent of gate electrification systems in place at the airport.

Airport staff were asked to gather some information in advance and to participate in a 1-hour web interview, ideally including staff representatives from multiple relevant departments, in addition to airline representatives or any other interested stakeholders. The case study questions were provided in advance and subsequently discussed during the interview to obtain all relevant information. Each case study summarizes key airport facts, gate electrification system configuration, financial and regulatory considerations, as well as challenges and/or best practices identified for that airport.

The case studies and surveys (described in Section 1.2.3) illustrate that most airports are not systematically tracking utilization of these systems.

1.2.3 Surveys

The third stakeholder outreach effort involved electronic surveying. Two online surveys were administered through Survey Monkey, a web-based platform designed for custom survey administration. (A summary of responses are included in Appendices B and C.) One survey was developed for airport respondents to gain additional insights beyond those gathered during the focus groups and case study interviews (see Appendix B). The second survey was developed to obtain the perspective of airline pilots (see Appendix C). As pilots have ultimate responsibility for and control over the aircraft (and, therefore, decisions with regard to the use or non-use of gate electrification systems), their input was critical to understanding how to address utilization challenges.

The questions on both surveys were developed based on feedback received during the focus groups and case study interviews, along with input from the ACRP project panel. The questions for airports included those on systems and equipment in place at the airport, how the systems were acquired and financed, how they are operated and maintained, what the barriers

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to utilization are, whether utilization tracking occurs (and if so, by what means), and other best management practices.

The airport survey was distributed through the Airports Council International–North America Environmental Affairs Committee and the American Association of Airport Executives Environmental Services Committee. Thirty-four airports responded to the survey, six of which were also either focus group or case study airports. Therefore, information was obtained from 28 additional airports. The focus groups, case studies, and airport survey collectively resulted in information gathered from 43 individual airports.

The airport survey responses were analyzed to determine the most commonly cited challenges to utilization, best practices, and utilization tracking practices. According to survey results and case study interviews, the majority of airports are not tracking utilization of electric PCA or ground power. The exception are those airports that have utilized VALE grants, and those airports are focused on estimating emissions savings as opposed to system utilization.

The pilot survey was distributed to individual airline representatives, along with staff at the Air Line Pilots Association, a trade association for commercial airline pilots. The airline representatives were asked to distribute to their pilot colleagues. Air Line Pilots Association staff offered to distribute the survey to one focal point in each airline pilot union in their membership, with the request that those individuals then distribute to the pilots within their own organizations.

More than 200 pilots responded to the survey. Although the majority of responses (>80 percent) came from pilots employed by one particular airline, the research team found that the responses of pilots from the dominant airline were very similar to responses provided by pilots employed by other airlines. Therefore, the pilot survey results were retained. The pilot responses are summarized in Appendix C.

1.3 Airport and Airline Stakeholders

As mentioned in the section above, a variety of relevant stakeholders are involved in the decision to acquire, install, operate, maintain, and use electric PCA and ground power systems. The exact stakeholder mix is expected to vary from airport to airport, but, in general, critical groups include airport management; environmental, operations, and maintenance personnel; airline corporate and airport-based staff; ground crews (either airport or third-party service providers); and pilots. This section briefly describes the various audiences for this report.

1.3.1 Airport Stakeholders

- **Management and Finance:** Airports are often the owner and maintainer of gate electrification equipment and systems (although sometimes airlines own these systems). Airport senior leadership and finance departments are involved in the decision to acquire gate electrification systems, and they must determine how to fund the purchase of the equipment. The airport (or airlines) may require a cost–benefit analysis before purchasing the equipment, and a key assumption in cost–benefit analyses is that the equipment will be maintained in good working order and used by airlines in lieu of APUs. Airport management and finance departments are, therefore, one target audience for this report and have an interest in understanding how to evaluate gate electrification systems’ use, as well as the factors that may contribute to the use or non-use of the equipment.
- **Environmental:** Airport environmental departments are typically responsible for understanding the airport’s contribution to local air quality and, in many cases, developing air pollutant and/or greenhouse gas emissions inventories. Airport environmental staff often

collect data and report performance related to environmental and sustainability goals that the airport has taken on. This reporting may require knowledge of emissions from aircraft while on the ground, as well as electricity and fuel use of airport-owned facilities and equipment. In addition, for airports that have received VALE grants for PCA and ground power equipment, airport environmental staff may be tasked with tracking the use of these systems to estimate emissions savings.

- **Facilities and Maintenance:** This category includes both in-house facilities and maintenance personnel (airport employees), as well as third-party service providers who are contracted by the airport to maintain gate electrification systems. Maintenance personnel are critical to ensuring that gate electrification systems are operable and returned to service quickly when repairs or replacements are needed. Many of the common challenges that affect utilization of these systems directly affect airport maintenance personnel. For example, misuse and accidental damage of gate electrification equipment can result in a higher workload for airport maintenance staff due to more frequent repair and replacement needs.

In many cases, airport maintenance personnel are responsible for maintaining multiple systems with competing priorities for repair (e.g., baggage conveyance systems or other electrical systems). Addressing higher numbers of work orders related to gate electrification equipment can result in delays in the recovery of other systems and lead to staff resource constraints.

- **Operations:** Airport operations staff work closely with airlines, as well as airport—or contracted—maintenance personnel to ensure a safe and efficient operating environment. When gate electrification equipment is out of service, the first point of contact for the airlines is often airport operations, who, in turn, alert maintenance departments. Airport operations staff are also involved when aircraft need to use airport-owned mobile ground power or PCA units at gates or remote parking positions.

1.3.2 Airline Stakeholders

Airline stakeholders reported a strategic objective to make available and use PCA and electric ground power at as many of their stations as possible to reduce APU operating cycles and operating hours.

- **Pilots:** Airline pilots are ultimately responsible for the safety and operation of their aircraft, as well as the comfort of the passengers. Pilots make the decision whether, when, and how long to utilize electric PCA and ground power and when to use the APU. Pilots reported—via the survey and in individual conversations—that they will use electric PCA and ground power when it is available and effective, and many airlines have policies in place requiring the use of electric systems, when available, in lieu of APUs. However, pilots must make the decision based on local conditions and passenger comfort. Pilots fly into multiple airports, and, therefore, experience varying levels of equipage and reliability of gate electrification equipment.
- **Ground Crew:** Airport ground crews—either airline employees or third-party ground crews contracted by the airline[s]—operate the gate electrification equipment and are responsible for proper connection of the aircraft. As such, they are critical stakeholders. They also communicate with pilots and airport staff with regard to the status of the equipment. According to the information gathered during the research process, ground crew often mishandle the gate electrification equipment, which results in equipment damage and unavailability.
- **Airline Corporate Staff and Station Managers:** Expenditure on jet fuel is often one of the largest—if not *the* largest—costs incurred by airlines. Therefore, airlines have a strategic objective to minimize fuel use, including APU use, where possible. Airline corporate staff—defined as airline staff not assigned to a particular airport—monitor fuel use across the fleet and at individual stations (i.e., airports). All of the airlines interviewed for this project reported the

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existence of some corporate policy in place requiring or encouraging the use of electric PCA and ground power when available, as an alternative to running the APU. In some cases, airline corporate staff will directly communicate with airline station managers or pilots when APU use is higher than normal, particularly when those aircraft are operating to or from airports with gate electrification equipment in place.

1.4 Summary of Findings

This project resulted in the identification of several common challenges affecting the use of gate electrification systems and potential solutions to address these challenges. In addition, there are three key findings from this research.

First, airports and airlines share the strategic objective to optimize the use of gate electrification equipment and minimize APU use both to save on fuel costs and APU maintenance and to reduce emissions of criteria air pollutants and greenhouse gases. Because this is a shared objective, there is an incentive for stakeholders to work together to improve system utilization.

Second, airports generally are not tracking gate electrification system utilization. Airports that have received VALE grants for the procurement of their systems do track equipment use for the purpose of estimating emissions reductions. However, those airports' activities are not focused on understanding whether equipment is being used to the maximum extent possible, and, if not, what the barriers to full utilization may be. Other airports reported that they do not track utilization because informal observations indicate that ground power and PCA equipment are being used frequently. The research team was unable to obtain historical or current ground power and PCA system utilization data from either airports or airlines, either because this information is not tracked or was not in a format that could be shared with the research team. The intent of the Utilization Tracking Methodology described in Chapter 5 is to serve as a simple tool to enable airports to more easily estimate utilization rates of their gate electrification equipment, and, therefore, to more accurately identify causes of non-use and appropriate solutions.

Third, communication between stakeholders is key to solving these challenges. Most of the solutions identified do not require significant investment in new technology or equipment, but they do require an investment of time and the collaboration of stakeholders. For example, airports typically provide and maintain the gate electrification equipment while the airlines operate it. Therefore, a cooperative approach is required to successfully address many of the challenges listed in this report and to improve system utilization rates.

CHAPTER 2

Ground Power and Air Conditioning Systems

Upon landing, aircraft taxi to the gate where passengers disembark and cargo and baggage is off-loaded. While at the gate, a variety of activities occur in preparation for the aircraft's next flight. During this time, aircraft require energy to power onboard systems. Aircraft are equipped with APUs. These engines not only provide the power necessary to start the main aircraft engines—the APU's primary purpose—but also continuously supply onboard power to support aircraft electronic systems (i.e., avionics) and heating and cooling needs. Like main aircraft engines, APUs are gas turbine engines and use jet fuel. However, once the aircraft arrives at the gate, on-ground power sources can provide an electric alternative to the onboard APU engine. This chapter provides an overview of aircraft power needs, power supply options, gate electrification equipment, and operations and maintenance considerations, as well as descriptions of the incentives driving the installation of gate electrification systems.

2.1 Aircraft Gate Power Needs

Aircraft parking time at the gate varies for different aircraft sizes and types, among other factors. Smaller aircraft with quick turnaround times stage at the gate for as little as 20 minutes. Larger passenger and cargo aircraft can remain at the gate for several hours, with unexpected delays potentially extending the stay. While parked at the gate, these aircraft have two primary power needs—electrical power and cabin-conditioning control—which are briefly described below.

2.1.1 Electric Power

The aircraft requires electric power for avionics and cabin operation. Aircraft undergo a variety of system checks while on the ground to verify functionality in advance of the next flight and to update system support for navigation. The flight plan is transmitted to the flight crew, reviewed, and loaded along with other information for the flight, such as onboard fuel and weather data.

As part of the process of cleaning the cabin and readying it for the next flight, electricity is needed for lighting and powering onboard water systems and other appliances, including refrigeration and kitchen equipment. The mechanics of the onboard water system is used as part of the cleaning process.

2.1.2 Cabin-Conditioning Systems

Maintaining a comfortable cabin temperature is important for efficient preparation of the plane between flights for crew, service personnel, and passenger comfort during departure and arrival.

Cabin temperature demands are highly variable based on the ambient on-ground temperature. According to the *VALE Program Technical Report* (FAA 2010), aircraft cabins typically require heating when ambient temperatures are below 45°F and cooling when temperatures are greater than 50°F. When temperatures are between 45°F and 50°F, aircraft cabins will typically need ventilation (though not necessarily cooling or heating). Demand for cooling is critical in warm climates, particularly during the second half of the day as temperatures rise, as well as in summer months. In colder climates, the demand for heating takes precedence. In extreme cold, cabin heating may be necessary to prevent water onboard the aircraft from freezing. During shoulder seasons (i.e., fall and spring) or in locations where weather is variable and unpredictable throughout the day, the air-conditioning needs of aircraft cabins may vary and ultimately are subject to pilots' discretion.

2.2 Power and Cabin-Conditioning Equipment

There are three main sources of power to meet aircraft power needs while on the ground: onboard engines (i.e., APUs), ground-based systems, and mobile units. This section describes the options for providing power to aircraft and provides a high-level description of ground power and PCA systems.

2.2.1 Onboard Engines

Aircraft APUs are engines that provide power for aircraft functions beyond propulsion. The APU is typically located in the tail of the aircraft (Figure 1) and is powered by the same jet fuel as the main engines. Its primary purpose is to provide power to start the main engines. Once the main engines have started, the APU is typically shut off. Additionally, most aircraft are able to use the APU during normal flight conditions as backup power sources or in case of generator failure.

The APU can also be used to provide a power supply to run the aircraft systems while on the ground between flights. In this case, the APU simply remains running while the aircraft is parked at the gate. Use of the APU to provide ground power is influenced by the expected time at the gate and availability of alternative power supplies.

As with all engines, some regular use is important to keep the APU functioning. But long idle times can result in buildup and clogging. However, the APU has an expected runtime life conditioned on adherence to a prescribed maintenance schedule. When the APU is used to

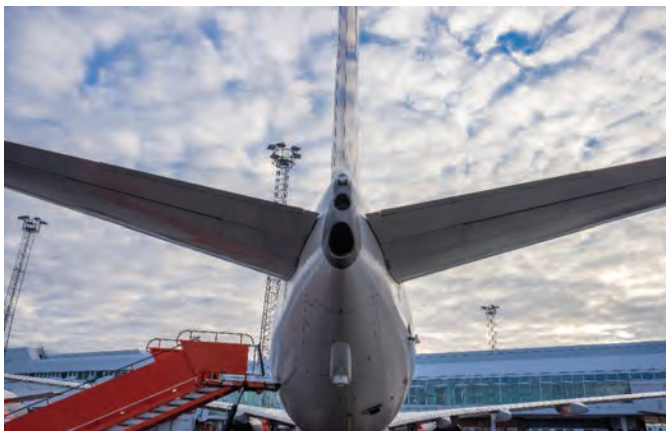


Figure 1. Aircraft APU.

regularly supply ground power to the aircraft, run time increases and maintenance schedules must be accelerated, often leading to an increase in overall maintenance costs. In addition, as the run time of the unit increases, it shortens the product life and requires accelerated component replacement and associated costs. Any time an aircraft is out of service due to unexpected APU maintenance needs, it may cause ripple effects across an airline's operations because of lack of availability of an aircraft for scheduled flight operations.

APUs are not designed or economical for use as routine sources of ground power. However, when gate electrification systems are unavailable (e.g., due to equipment misuse or damage), pilots must use aircraft APUs to provide ground power while at the gate, increasing the wear on the engines. APUs are also utilized when ambient temperatures exceed the operating limits of the PCA system or when the PCA system is not sized appropriately for the aircraft model (i.e., the system is not powerful enough to heat or cool the aircraft models in use; or, in some cases, the system is too powerful). In these instances, APUs provide air supply, as well as energize the air-conditioning system on the aircraft to heat or cool the supply air to maintain a comfortable cabin temperature.

2.2.2 Ground-Based Electric Power and PCA

The primary alternative to using the APU at the gate is ground-based electric power, which can be provided through a ground power unit (GPU) frequency converter with power supplied by the airport terminal. Alternatively, power can also be provided by a mobile ground support equipment unit, an option described in more detail in Section 2.2.3. The power must be converted to a voltage and frequency that is compatible with the aircraft systems. This is achieved through the GPU frequency converter.

Cabin conditioning can also be powered on the ground instead of by engine. However, an air-conditioning unit—referred to as a PCA unit—is necessary to provide efficient heating and cooling to the aircraft. Like the GPU, the PCA unit may be physically connected to the terminal via the gate or as mobile ground support equipment. Figure 2 shows a schematic of an aircraft parked at the

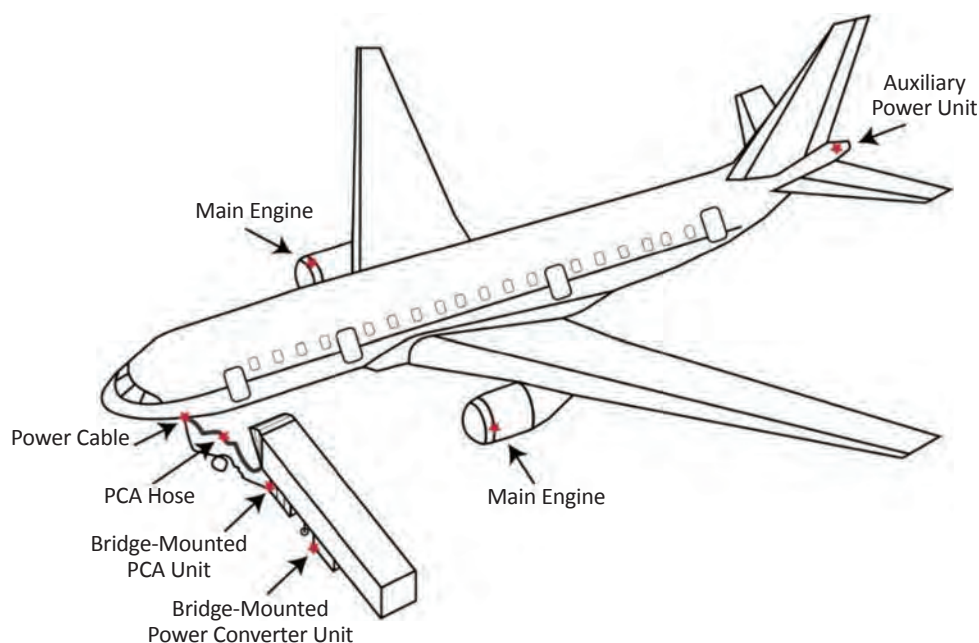


Figure 2. Typical location of aircraft main engines, APU, and gate electrification equipment.

gate, with a jet bridge-mounted PCA and ground power unit, along with a PCA hose and power cable connecting the aircraft. Figure 3 depicts the GPU frequency converter and the PCA unit positioned on the underside of the jet bridge, a common design for gate electrification equipment.

Even at airports where gate electrification equipment and services are available, the APU remains operational for a short time during the transition at the gate. It is estimated that APUs are used for approximately 7 minutes per aircraft turn (2 minutes when aircraft first arrive at a parking position and for approximately 5 minutes prior to pushback [Environmental Science Associates et al. 2012]). FAA also assumes that—as stated in the *VALE Program Technical Report*—APUs must be used for a minimum of 7 minutes per turn (time at gate during passenger loading and unloading operations), even if gate electrification equipment is available (FAA 2010).

2.2.2.1 GPU Frequency Converter

As previously described, the GPU can be any equipment on the ground that supplies power to the aircraft. The GPU frequency converter specifically transforms the terminal's power delivered from the electrical grid and consumed in the airport terminal to 400 Hz, a frequency that can be utilized by most aircraft. Smaller aircraft, such as regional jets, often are designed to use 28 volts direct current (VDC) power, and GPUs may be capable of serving both types of aircraft. The majority of airports interviewed and surveyed for this project provide electric 400 Hz power, with far fewer gates equipped with electric 28 VDC power. Therefore, discussions of electric ground power equipment and utilization in this report generally refer to 400 Hz, unless stated otherwise.

When the unit is located at the gate, it is referred to as point of use. The unit may be located on the underside of the jet bridge—often close to where it connects to the aircraft—or on the ground if there is insufficient space to accommodate the unit on the bridge. It may also be part of a centralized system with primary components located in the terminal building with a smaller gate box unit with controls located on the jet bridge. Some airports have GPUs located in underground pits to minimize equipment on the ramp.

The GPU frequency converter is connected to the aircraft with a cable (Figure 4), which is manually attached by the ground crew.

2.2.2.2 Preconditioned Air

The PCA unit provides cooling, heating, and ventilation to the aircraft. Conditioned air is supplied through a large air-conditioning unit attached to the underside of the jet bridge



Figure 3. Gate electrification equipment attached to a jet bridge (Source: Steve Bivens, Cavotec).



Figure 4. Aircraft connection to ground power (black cable) with frequency converter (red arrow), and PCA hose (yellow ribbed hose).

(bridge mounted), on the ground adjacent to the bridge (ground mounted), or from a central location inside the terminal, as illustrated in the schematic in Figure 5. Point of use PCA units may provide cooling and ventilation exclusively or have the ability to provide heating if a heat pump is included.

Central systems provide heated or chilled liquid to each gate through a series of pipes. Each gate unit contains a heat exchanger across which air is moved before being pumped into the aircraft. The liquid is heated or chilled from a central chiller or boiler unit at the airport and may be part of the airport's overall HVAC system. With central PCA systems, an air-handling unit is typically still necessary at the gate to blow the conditioned air into the aircraft. The ground crew delivers the heated and cooled air through a flexible hose that is unrolled and connected manually to the underside of the plane.

2.2.3 Mobile Ground Power and Mobile PCA Units

Ground support equipment refers to a variety of vehicles (such as fueling and baggage transport) used on the airside apron to support aircraft when parked at the gate. Ground support equipment may also include mobile 400 Hz or 28 VDC GPUs or mobile PCA units to serve multiple gates as an alternative to APUs when electric ground power and PCA are not available.

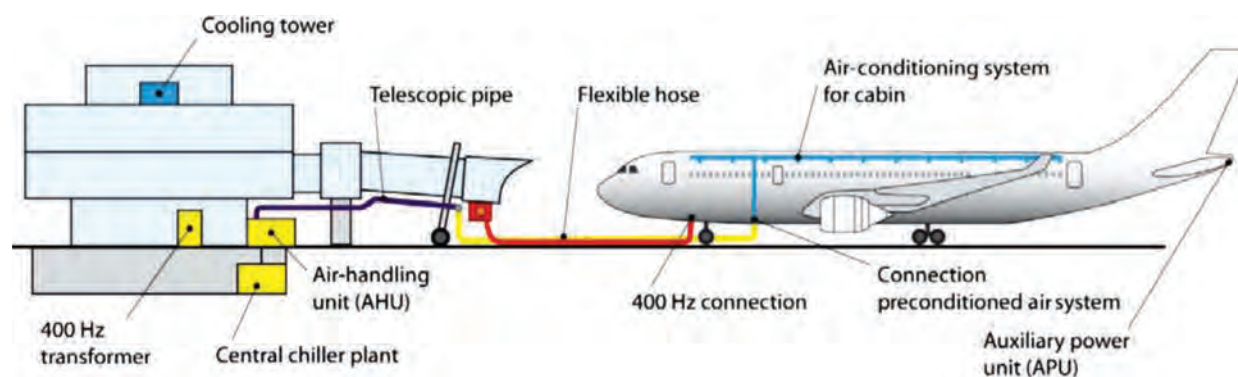


Figure 5. Typical layout of gate electrification system and centralized cooling system (Fleuti and Ruf 2013).

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Figure 6. Mobile battery-powered GPU, ITW GSE Model 7400 (Source: ITW GSE).

The GPU and PCA mobile units are typically powered by fossil fuels (diesel or gasoline). Some units are powered from electricity supplied either from an onboard battery or by plugging into an outlet at the gate. In 2018, a mobile battery-powered GPU entered the market (Figure 6), though mobile PCA units require too much power to run on batteries at this time.

Fossil fuel-powered ground support equipment have been utilized most commonly where APUs are discouraged—or when airlines prefer to use ground support equipment instead of APUs for economic reasons—and in cases in which the airport is not equipped with other means of providing electric ground power or conditioned air.

When aircraft are parked at gates with unavailable gate electrification equipment, or equipment that is not sized or configured appropriately for the aircraft (e.g., a regional jet requiring 28 VDC power parked at a gate that only has 400 Hz available), mobile units may be used. In addition, remote gates and hardstands—gates not attached to the terminal building by a jet bridge—that are not in close proximity to the terminal and associated power infrastructure are often supported by mobile units.

Whether in use at a gate or a hardstand, the mobile unit is attached to a tug and driven to the aircraft location for service. The tug also requires power, which may be supplied by an onboard battery or a traditional combustion engine. A schematic of a mobile PCA is provided in Figure 7.



Figure 7. Schematic of tug-towed mobile PCA unit.

A considerable number of ground support equipment vehicles are often operating simultaneously on the ramp to serve aircraft needs at the gate, particularly at commercial service airports. In addition to mobile GPUs and PCA units, there may also be baggage tugs, catering vehicles, fueling trucks, lavatory servicing equipment, deicing equipment, and water cabinets in service on the ramp. Therefore, ramp traffic congestion and vehicle storage associated with mobile units should also be considered when selecting the type of gate electrification equipment to employ.

2.3 Operations and Maintenance

Gate electrification equipment is typically owned and operated by the airline or the airport, as discussed in Section 2.5. Most of the airports interviewed for this project owned all or the majority of gate electrification equipment at the airport. Maintenance is performed by a number of different parties, including airport staff, contracted third parties, and equipment manufacturers. There are several operations and maintenance variables that may impact the use of gate electrification equipment, including the competency of ground crew operators, the functionality of monitoring equipment, and equipment maintenance scheduling considerations.

2.3.1 Ground Crew Operators

The gate electrification equipment requires action by the ground crew to physically connect the gate equipment to the aircraft (Figure 8). This is conducted by extending the GPU power cable and the PCA hose from its position at the gate and connecting it to the underside of the aircraft.

The ground crew must be trained in the proper use of the equipment or it may be damaged and become inoperable. Ground crew must also be instructed by the managers—either at the airport or from the airline—about the necessity of using the gate electrification equipment. If aircraft are not connected to the gate electrification equipment, or not connected quickly enough, the pilot may instead continue to run the aircraft APU for ground power. If the ground crew is unable to use the gate electrification equipment because of damage, crew members must have access to direct communication with airline and airport operations staff to alert them to take action to repair the equipment.



Figure 8. Ground crew connecting jet bridge at San Diego International Airport (Source: San Diego International Airport).

2.3.2 Monitoring Equipment Functionality

Gate electrification equipment owners and maintainers—whether they are employed by an airline or the airport—must be able to determine if the equipment is functioning properly and being put into service. Airports monitor the functionality of their equipment in varied ways, often including some combination of the following actions:

- Conducting regular manual equipment checks;
- Relying on operators to report malfunctions; and
- Utilizing centralized monitoring systems, such as building automation systems or central HVAC controls.

The monitoring capabilities in place at each airport depend on the equipment installed, equipment ownership structure, maintenance responsibility, and metering availability (including gate electricity meters and gate electrification equipment use meters).

Many newer gate electrification systems include options for remote monitoring through a connection that transmits activity information to a centralized control center, where the information may be viewed from a central location or from an Internet-enabled device—such as a computer or smartphone—as illustrated in Figure 9. The information available may vary, depending on the interests and access level of the user. However, a monitoring system generally provides real-time information about the operational status of the gate equipment, including equipment that is in active use, faulty, in maintenance, or remains idle. A depiction of electrification equipment operational status by gate for a single concourse is shown in Figure 10. Figure 11 depicts a screenshot of Seattle–Tacoma International Airport’s software interface for monitoring the PCA status of individual gates. This airport has a central chiller and boiler plant that provides heating, cooling, and ventilation to the PCA system, which is incorporated into the airport’s HVAC system. The PCA monitoring software has been integrated into Seattle–Tacoma International Airport’s building automation system.

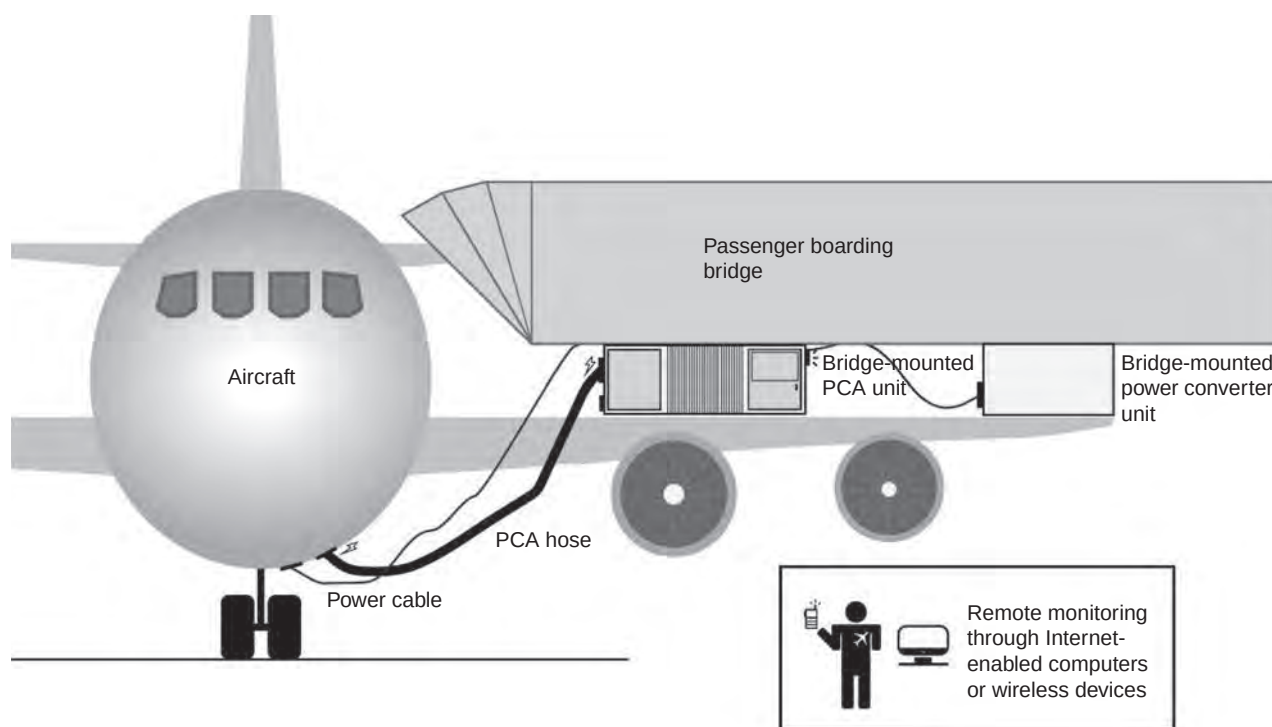


Figure 9. Diagram of gate electrification equipment at a jet bridge (passenger boarding bridge) being accessed remotely.

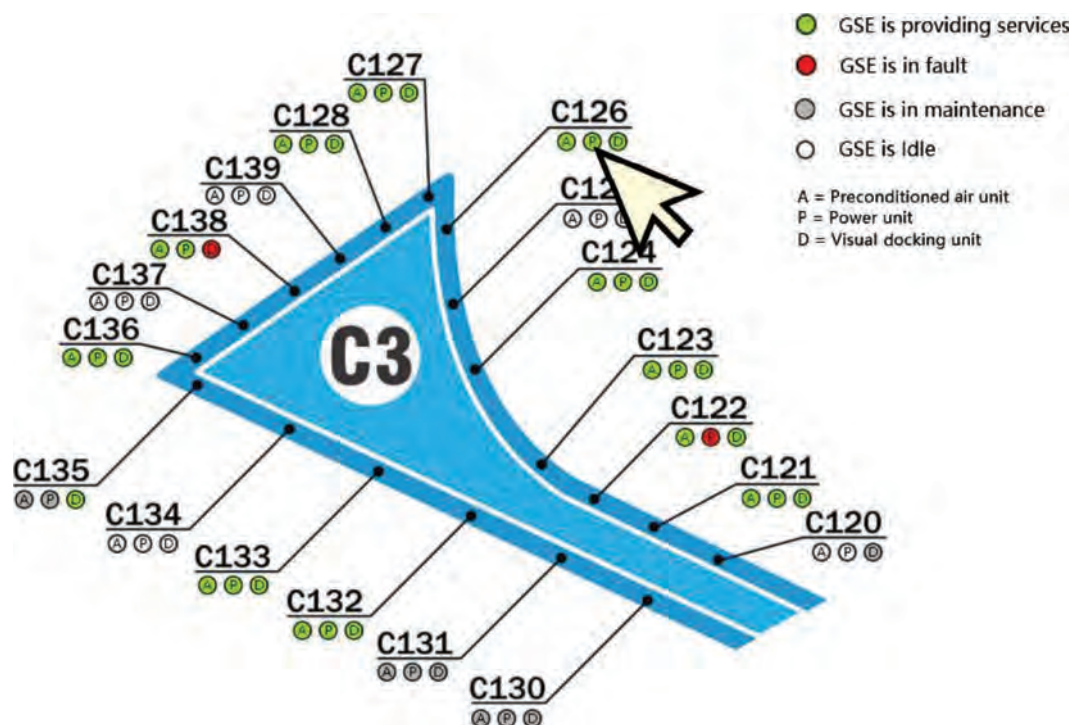


Figure 10. Software display for gate equipment tracking and monitoring (GSE = ground support equipment) (Source: Steve Bivens, Cavotec).

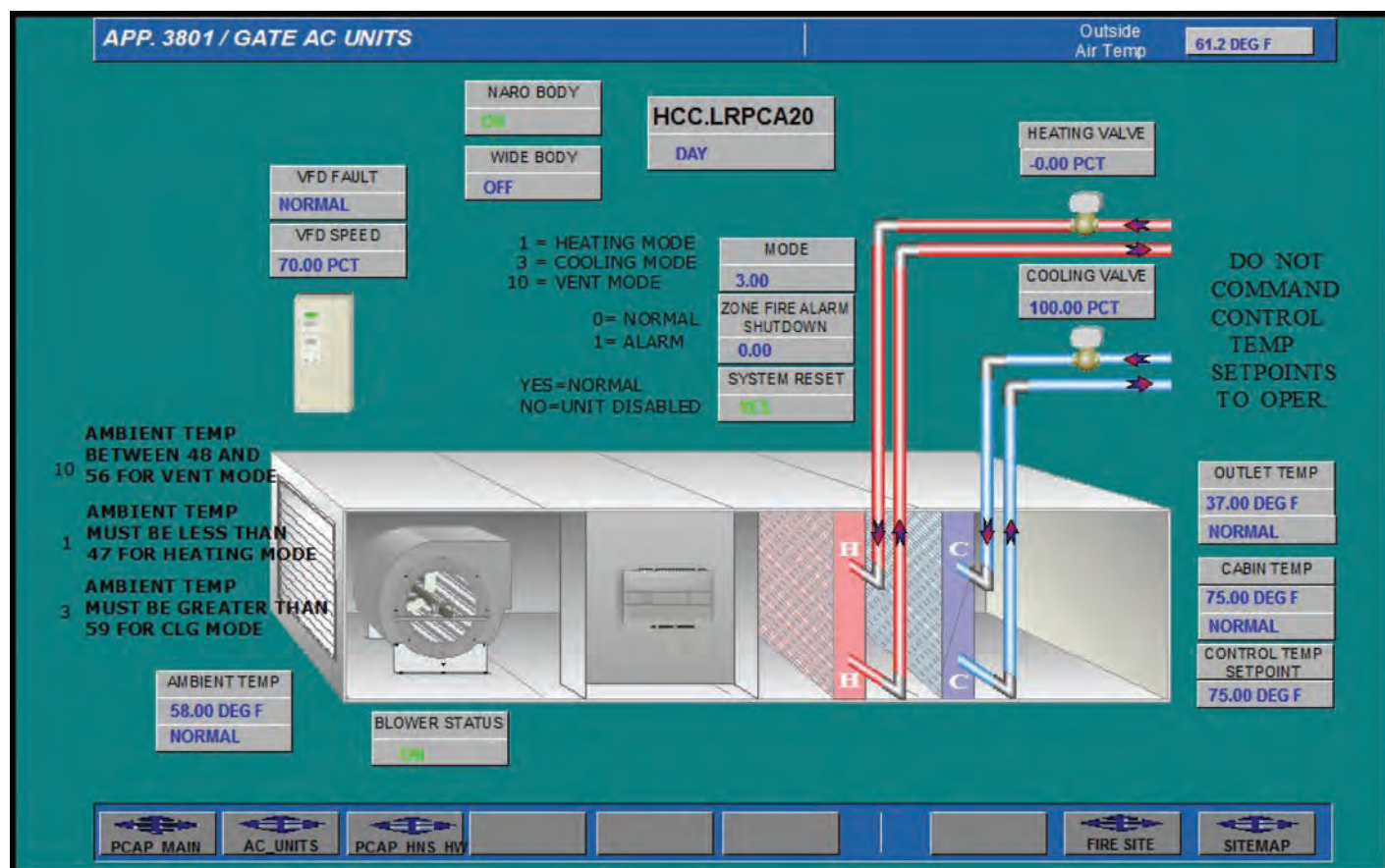


Figure 11. PCA unit monitoring software interface for one gate at Seattle-Tacoma International Airport (Source: Seattle-Tacoma International Airport).

If a remote monitoring system is not a component of the gate electrification system's configuration, usage may be monitored by installing a meter at the point where the GPU and PCA units are connected to the terminal. Such a meter may also be tied into a centralized monitoring system—such as an airport's existing building management system or building automation system—to allow for remote monitoring using existing systems. If monitoring information is not tied into a centralized system, confirming equipment functionality may require staff to physically inspect the equipment, which can be time consuming and inefficient.

Absent the ability to electronically monitor use and functionality of gate electrification equipment (or to provide supplementary information), owners and maintainers may choose to undertake formal or informal surveys to observe how the gate electrification equipment is being employed. These visual surveys are useful to confirm if the PCA and/or ground power equipment is physically connected to the aircraft but cannot necessarily confirm if the equipment is actually in use. While each of these monitoring options can be used to assess the operations of the gate electrification equipment, none of these systems is useful in confirming whether the APU has been turned off. APU use is monitored by some airlines to understand fuel consumption. However, that information is not regularly provided to airports.

2.3.3 Equipment Maintenance

Like other aircraft service equipment, the gate electrification components should be inspected and maintained according to a regular preventative maintenance schedule to avoid operational failure. In addition, quick response time concerning corrective maintenance is necessary to maximize equipment availability in the event of an unexpected breakdown. All require sufficient budget, staff, and inventory on hand to ensure minimal repair time when problems do occur. As discussed in Chapter 3, equipment availability is heavily impacted by improper use and storage of gate electrification equipment components and maintenance practices, which can speed or hinder the return to service of the equipment. For example, making spare parts available and even storing backup units that can be deployed quickly as a replacement will reduce equipment downtime and loss of service.

2.4 Ownership Models for Gate Electrification

Gate electrification systems may be owned, operated, and maintained by individual airlines or by the airport, or by any combination thereof (i.e., equipment may be owned by the airport but maintained by the airlines).

2.4.1 Owned by Airline

Terminal and gate use and ownership vary from airport to airport and often change over time. At some airports, airlines own (or used to own) their gates or have exclusive use or preferential use leases (i.e., they do not share gates with other airlines). In other cases, multiple airlines may share the same—or common—gates. In some airports where airlines own or have exclusive use leases of gates, airlines have acquired and operate their gate electrification equipment to meet their respective operations and maintenance needs. The deployment and utilization of gate electrification equipment supports airline economic interests by reducing the use of the APU. This, in turn, increases its useful operational life and decreases costs associated with powering the aircraft at the gate using jet fuel.

In the airline-owned scenario, the airline workers—or their contractors—operate and maintain the gate electrification equipment. In some cases, the airlines also maintain their own

jet bridges and ancillary equipment. Interactions between the ground personnel, pilots, and onboard crews remain within the same company, which may improve consistency of communication and use of the gate electrification system, since company policies and procedures apply to all parties.

2.4.2 Owned by Airport

It has become more common for airports to invest in gate electrification equipment to maintain greater control over facilities, to meet airline needs, and to manage environmental impacts better. In some cases, airports have reassumed ownership of gates and equipment that were previously owned by airlines. Access to funding available from FAA and other government entities has also encouraged airport investment in the equipment (e.g., through VALE grants or state grant programs).

In the airport-owned scenario, airport workers or their contractors maintain the gate electrification equipment (although airline ground crew often predominately operate the equipment). Interactions occur between the ground personnel, the pilot and onboard crew, and airport staff. Airlines may have their own policies and procedures with regard to APU use, which can be facilitated or hindered based on whether the airport has the appropriate gate electrification equipment. In some cases, U.S. airports have policies encouraging airline use of gate electrification equipment instead of APU use. But none of the U.S. airports interviewed and surveyed for this research project have policies mandating the use of gate electrification systems.

2.5 Motivations for Installing Gate Electrification Systems

Whether the airline or the airport owns and/or operates the gate electrification systems, there are a number of reasons why these systems are more frequently being installed to provide ground power and cabin conditioning at airports. This information can be useful in understanding potential solutions for optimizing their use.

2.5.1 Preserve APU Critical Functionality

Use of the gate electrification equipment while the aircraft is on the ground decreases use of the APU. This switch allows the APU to be preserved for its primary purpose, which is to be available to start the main aircraft engines prior to flight or—in the event of an interruption—during flight. As a result, airlines are placing greater emphasis on reserving the APU for these safety reasons.

2.5.2 Reduce Aircraft Operational Costs

Complementing the preservation of the APU is the additional economic benefit to the airline from using the gate equipment instead of the APU. The economic benefit can come in two forms. First, when the APU is not used as often, maintenance and replacement costs are pushed further out into the future, which decreases associated costs on an annual basis. Second, operating the APU burns jet fuel, which, in most cases, is comparatively expensive. While airports use a variety of systems to charge airlines for electricity use, the cost of electricity is cheaper than jet fuel. Therefore, costs to the airline for using the gate equipment are often lower. Optimizing the use of gate electrification systems, then, will accelerate the return on investment for the costs to install the equipment. Labor costs for the ground crew are comparable for APU use and gate electrification equipment use.

2.5.3 Local Air Quality and Noise Improvements

As discussed in Chapter 1, running the APU emits pollutants from the APU exhaust at the back of the aircraft, while increasing associated noise on the ramp. These emissions and related noise can impact ramp workers and communities adjacent to the airport. For these reasons, many airports—most outside of the United States—have enacted policies restricting the use of APUs. The Boeing Company manages a list of international airports with airport noise and emission regulations (The Boeing Company 2018).

Converting to gate electrification equipment decreases localized air pollution from running the APU on site at the airport, though emissions are still associated with producing electricity off site and pulling it from the electrical grid. The gate electrification equipment does emit noise, as well. However, the noise is at lower levels than an APU (Tam et al. 2005, Kwan and Yang 1992). Reducing local emissions is particularly important in urban areas that have been designated as nonattainment zones (i.e., those areas not meeting air quality standards) under the federal air regulations.

While direct impacts on neighboring communities remain a strong motivation for airport improvement projects, airport authorities are also developing broader environmental and sustainability goals consistent with the public policies of local, regional, and state governments. Sustainability goals have been implemented at airports that seek to be leaders in the industry, as well. The conversion of ground power to electric sources may assist airports in contributing to many of these environmental initiatives, not only improving local air quality but also decreasing the airport's greenhouse gas emissions when comparing APU emissions to those associated with the gate equipment's electricity demand.



CHAPTER 3

Challenges Affecting Gate Electrification System Utilization

The objective of this report is to identify and document factors that affect the use or non-use of gate electrification systems and to subsequently present potential solutions to optimize utilization. During the report development, a number of airport stakeholders, airlines, pilots, service providers, and equipment manufacturers provided information to the research team concerning the most commonly observed barriers—or challenges—to electric PCA and ground power utilization. This chapter provides information about the challenges reported and experienced by airports and airlines most frequently, some combination of which are likely to occur at most airports. This report intends to provide information that is general enough to be applicable to a broad range of types and sizes of airports located in varied climates, although individual airports may face additional challenges specific to their unique site, location, or operations—among other factors—that may not be captured in this document.

The research team identified a list of 19 challenges, organized into six high-level categories that are listed in Sections 3.1 through 3.6. The six high-level categories include: 1. Training and Communications, 2. Operation of Equipment, 3. Maintenance of Equipment, 4. Resource Constraints, 5. Climatic Factors, and 6. Policy and Regulatory Factors.

Many of the challenges are interrelated, and several of them could be considered as different facets of the same challenge. For example, damaged power cables and kinked hoses are listed as separate challenges, but they are also both symptoms of insufficient training of ground crew. Those two items are listed separately, however, due to the frequency with which they were raised as individual issues by industry stakeholders during the report development. In addition, depending on the airport and underlying causes of each challenge, there may be more than one appropriate solution.

This project included development of the Self-Assessment Checklist (an Excel-based tool), designed to be used with guidance from the report. The checklist is intended as a high-level screening tool that serves as a resource for stakeholders to identify their challenges and assess how impactful they are to utilization at a particular location. The 19 challenges are listed in the Self-Assessment Checklist by presumed relative impact on utilization and by relative ease of implementing solutions (assigned a number 1 through 19). The specific impact of each challenge on utilization rates will vary at individual airports. The lack of data on historic utilization rates makes specific impacts of each challenge impossible to determine for the purposes of this report.

Table 1 depicts the challenges by high-level category and their corresponding number on the Self-Assessment Checklist. The checklist organization and further detailed instructions for its use are described in Section 3.7.

Potential solutions to the 19 challenges included in this chapter are described in Chapter 4. The solutions are organized according to high-level category and identified as either short-term or long-term solutions (depending on the relative level of effort and resources required to implement).

Table 1. Challenges affecting PCA and ground power utilization.

Utilization Challenges			
Challenge Category	Challenge	Corresponding Solutions (Chapter 4)	Challenge Number on Self-Assessment Checklist
Training and Communications	Compliance with airline standard operating procedures	1, 3–6, 8, 12	1
	Insufficient number or training of ground crew	1, 5, 6, 9, 11–13, 26	5
	Lack of communication on equipment availability status and equipment use	1–3, 7, 9, 17, 20, 23, 25	10
Operation of Equipment	Kinked or improperly positioned PCA hoses	4–9, 11–13	2
	Damaged power cables or PCA hoses	4–13	3
	Preset PCA temperatures not aligned with ambient temperatures	23, 32	13
Maintenance of Equipment	Inoperable equipment (reasons other than those listed above)	4–7, 9, 10, 13, 15–19, 21, 25	4
	Lack of on-site spare parts inventory	15–18, 22	7
	Damaged aircraft ground power receptacle	17, 21	8
	Clogged aircraft air intake duct	15, 17	17
Resource Constraints	Insufficient availability of maintenance personnel	19, 22	6
	Insufficient maintenance budget for systems	16, 17, 22, 24, 26, 27, 33	9
	Insufficient budget for renewing and/or “right-sizing” ^a systems	26, 27, 33	11
	Lack of electric PCA or ground power at hardstands	1, 3, 27	16
	Equipment not individually metered; lack of utilization tracking capabilities	2, 3, 27, 33, 34	18
Climatic Factors	Ambient temperatures exceed design standards of PCA system	27, 28, 30–33	12
	Weather conditions unsafe for ground crew to connect aircraft	29	15
Policy and Regulatory Factors	Short aircraft turn times ^b precluding use of PCA and ground power	4, 5, 9, 13, 30	14
	Lack of regulatory driver	1–3	19

^aRight-sizing is having sufficient capacity to condition the aircraft size presently operating at the terminal gate.

^bTurn time is the time from when an aircraft arrives at a gate to when it departs.

3.1 Training and Communications Challenges

A number of problems identified during the focus groups, case studies, and surveys were attributed to either insufficient training or a lack of communication between affected stakeholders. Related challenges are described in this chapter.

3.1.1 Ground Crew Noncompliance with Airline Standard Operating Procedures

Most airlines have established maximum allowable times for ground crews to connect both ground power and PCA systems to aircraft upon arrival at the gate (e.g., within 5 or 10 minutes of aircraft arrival at gate). If ground crew do not connect aircraft in a timely manner, pilots are likely to start and use the APU for the duration of time they are parked at the gate. A quick

connection is imperative, particularly for aircraft with short turn times (i.e., the time an aircraft arrives at a gate to when it departs). However, in some cases, if the turn time is extremely short, the pilots may leave the APUs running regardless of how quickly gate electrification equipment is connected. This issue was identified by a majority of the pilot survey respondents (greater than 70 percent) as an issue they have experienced that causes them to use the APU instead of PCA or ground power.

This challenge could result from ground crew lacking awareness of the airline's standard operating procedure for connecting aircraft to gate electrification equipment within a specified time, insufficient numbers of ground crew required for proper connection of the aircraft within a specified time frame, or lack of a mechanism for holding crew accountable for following the standard operating procedures.

3.1.2 Insufficient Availability or Training Of Ground Crew

Given the need for rapid connection of ground power and PCA systems to an aircraft, a sufficient number of properly trained ground crew must be staffed to service aircraft. Ground crew must be properly trained to operate gate electrification systems in accordance with the manufacturers' operating instructions, as failure to do so can lead to premature deterioration of the system components. In cases where ground crew members assigned to connecting systems to the aircraft are not immediately available, pilots will likely start and/or leave the APU running.

Airport and airline stakeholders reported that high turnover of ground crew employees is a common occurrence. This results in staff with less overall experience and lack of familiarity with proper operation of the equipment. Inexperienced ground crew operating PCA and ground power equipment result in higher incidences of equipment damage from mishandling. Ensuring proper training can be a challenge when organizations experience high turnover. Ground crew employees also may not be aware of the importance of the use of electric PCA and ground power as an economically and environmentally beneficial alternative to the APU. Lack of awareness of the importance of this strategic objective affects the motivation to ensure proper handling of equipment.

In addition, ensuring that ground crew are properly trained can be challenging at airports that have multiple types or models of PCA or ground power equipment, each with differing system configurations and operating procedures.

The stakeholders responsible for providing ground crew training on the operation of PCA and ground power and for determining the frequency and content of the training may differ from airport to airport. Airlines develop training programs for their own employees and also utilize third-party service providers. Ground service providers also develop their own training programs, and those companies that service multiple airlines at a single airport report that their staff members are required to satisfy the individual training standards set forth by each airline. Although each group has its own training programs in place, inconsistencies between these programs may lead to confusion and errors.

Airports may provide training to airline staff or third-party service providers on the proper operation of airport-owned gate electrification equipment. Some airports reported that they provided training to operators through the equipment manufacturers (on site at the airport and at the manufacturers' facilities). Some airports reported that even though they own the gate electrification equipment, they do not provide training to airline staff or contractors due to liability concerns (e.g., if such staff subsequently cause damage to airline-owned equipment while operating gate electrification equipment). Instead, airports depend on airlines and contractors to train their ground crews according to equipment manufacturers' specifications.

3.1.3 Lack of Communication Between Parties Concerning Equipment Availability Status and Use of Equipment

Consistent and trackable communication with regard to gate electrification system status between ground crew and the maintenance provider is essential for ensuring awareness of system availability, and, therefore, utilization. A lack of effective communication from the ground crew to maintenance personnel with regard to an out-of-service system (or consumable part) can lead to delays in repair. Likewise, a lack of prompt communication from maintenance personnel to the ground crew—either directly or through airport operations or airlines—that the equipment has been restored to service may result in the incorrect assumption by ground crew that it is still out of order.

In addition, communication between the ground crew and the airline pilots with regard to system availability status is essential for ensuring system utilization. A lack of effective communication from the ground crew to the pilot with regard to system availability and connection status may result in the pilot choosing to start and/or leave the APU running, even when gate electrification equipment is operable.

3.2 Operation of Equipment

One of the most frequently cited challenges to optimal system utilization is the misuse of and subsequent damage to the equipment by users. This challenge was identified by all stakeholders as a common problem. Misused or mishandled components become damaged, do not function properly, and require repair and replacement more frequently. Many of these problems are symptoms of another challenge; specifically, ensuring sufficient training for ground crew (system operators). However, because these items were identified repeatedly by stakeholders as separate issues, they are listed in this section.

Operator errors can be identified by system owners, through a review of maintenance logs and work orders. Comparison of the frequency of repairs and replacement parts needed with the expected useful life of the equipment is another way for system owners to identify reoccurring errors. Simple observation of ramp operations by the system owners, maintainers, and users also yields insights into this challenge (e.g., PCA hoses or power cables run over by ramp equipment, dragged on the ground, or turned off improperly with the emergency stop button).

3.2.1 Improperly Positioned (“Kinked”) PCA Hose

A fold, or kink, in a PCA hose can impede air flow to the aircraft (Figure 12), resulting in insufficient heating or cooling of the aircraft cabin. Pilots reported that they will turn on the APU if the PCA cannot keep aircraft cabin temperatures comfortable for passengers. Hose kinks result from ground crew failure to deploy the proper length of hose (e.g., if too much hose is deployed, kinking is more likely), or ground crew do not ensure that hoses are laid flat when deployed. Hoses can also become kinked when they are not stored properly. Over time, frequent kinking of the hose may result in permanent damage to the component, requiring replacement.

3.2.2 Damaged Ground Power Cable or PCA Hose

Ground power cables and PCA hoses can become damaged through normal wear and tear but also as a result of improper use. These consumable items are essential to providing power and conditioned air to the aircraft. If either of these items is not in good operating order, pilots are likely to start and/or leave the APU running. For example, if power cable heads are dropped repeatedly or dragged across the ramp area, the cable heads and connecting pins may become bent or broken and render the cable inoperable. PCA hoses can tear or rip if repeatedly dragged



Figure 12. Kinked PCA hose (Source: Seattle–Tacoma International Airport).

across pavement. In addition, if the items are not retracted and stored properly, they may be subject to damage as a result of being run over by jet bridges or other ground support equipment vehicles on the ramp.

3.2.3 Preset PCA Temperature Settings Not Aligned with Ambient Temperatures

Centralized PCA systems provide either chilled water or hot water to cool or heat the air, which is then supplied to the aircraft, ensuring passenger comfort and safety. These systems can be programmed to automatically switch from heating to cooling mode and vice versa. Change-over dates are normally selected based on typical seasonal temperature patterns, although daily temperature may fluctuate in many climate zones, particularly in shoulder seasons. Ambient air temperatures may fluctuate from historical patterns at any time of year, as well, resulting in unseasonably warm or cool days.

If centralized PCA system settings are not adjusted to account for these temperature fluctuations (either day to day or within a 24-hour consecutive period), the system may be unable to effectively cool or heat the aircraft. In this case, pilots may be required to start and/or leave the APU running to control cabin temperatures better. The level of effort to adjust temperatures in real time may depend on the flexibility of the system controls and programming and presents a greater challenge in locations with highly variable weather.

3.3 Maintenance of Equipment

Regularly scheduled preventative maintenance of equipment, as well as rapid return-to-service maintenance when equipment requires repair, is essential to maintaining system operability and ensuring high utilization. The following challenges are related to maintenance topics.

3.3.1 Inoperable Ground Power and/or PCA System

Airports, airlines, and pilots all reported that inoperable gate electrification equipment is a persistent challenge affecting utilization.

In addition to the specific issues identified in Section 3.2 (kinked hoses and damaged power cables), component failures can occur for a variety of reasons. For example, airports and equipment manufacturers reported a reoccurring issue in which ground crew use the emergency shutoff button on equipment instead of shutting the equipment down properly. Over time, this action causes equipment to malfunction or wear out more quickly. Airports also reported additional examples of issues leading to inoperable systems, such as water damage to equipment installed on the top of jet bridges, equipment short circuits, and unreliable equipment that malfunctions without obvious causes.

In addition, as systems reach the end of their useful operating life, component failure rates rise. When system components wear out on older equipment, replacement parts may be difficult or impossible to source, leading to additional costs and time out of service.

3.3.2 Lack of On-Site Spare Parts Inventory

As stated in Section 3.3.1, spare parts or replacement units are not always immediately available from manufacturers. Long delays in obtaining spare parts, either due to low stock or component production discontinuation, contributes to system unavailability and affects utilization. This is an especially apparent problem at airports with aging PCA and/or ground power equipment. Some airports keep a spare parts inventory on site for components that fail more frequently or are difficult to obtain. However, a spare parts inventory is not always possible due to insufficient maintenance budgets, or the original equipment supplier no longer supports the product. Even when the airport or provider of maintenance services has a spare parts inventory, other components may need replacing that are not included in the inventory. Keeping a sufficient inventory of spare parts can also be challenging at airports that have multiple types, models, and ages of PCA or ground power equipment.

3.3.3 Damage to Aircraft Power Receptacle

Aircraft with damaged power receptacles are often unable to accept ground power, even if the ground power cables are physically able to connect. If the receptacles are unable to accept electric ground power, the pilots often have to start and leave the APU running. Problems with the aircraft receptacle may not be visible or obvious to ground crew. As a result the ground crew may assume that the ground power equipment is damaged or malfunctioning and report to it to the airport for creation of a maintenance work order.

3.3.4 Clogged Aircraft Air Intake

It is possible for debris from insulated PCA hoses or other matter to be ingested into the aircraft air-conditioning duct. As such, a pilot may perceive that the PCA is either not turned on or not performing properly due to insufficient air flow within the cabin of the aircraft, which may lead to APU use. This condition is usually discovered when an aircraft is taken out of service for comprehensive maintenance checks, referred to as a “C check.”

3.4 Resource Constraints

Various types of resource constraints—such as insufficient numbers of staff or lack of funding for system acquisition, operation, and maintenance—can impact system utilization. These challenges may be the root cause of other issues, such as time needed to repair systems, malfunctioning or out-of-service equipment, and insufficient training.

3.4.1 Insufficient Availability of Maintenance Personnel

Gate electrification system utilization depends, in large part, on its reliability. In turn, system reliability is affected by maintenance practices. Maintenance personnel must be available and trained to carry out routine or preventative maintenance on system components and to quickly restore systems when problems occur. If an airport, airline, or contractor—whoever is responsible for system maintenance—does not have a sufficient number of maintenance staff on hand with the necessary skill level, system restoration will be delayed. This may be due to system or component failures during off-peak hours, such as evenings or weekends when personnel are on call rather than on location. Some maintenance providers may be located away from the airport and require an extended response window to address each work order as it is received.

While systems are down, pilots will have to start and/or leave the APU running. Pilots also reported that they will leave the APU running by default—without even trying the PCA or ground power—when serving airports where they have experienced persistent problems with system reliability. Ensuring adequate numbers of maintenance staff with the necessary skills to repair equipment in a timely manner is both a resource constraint and a training challenge.

3.4.2 Insufficient Maintenance Budget

Maintenance budgets may be strained due to labor needs and stock requirements. Budgets must be sufficient to allow for an adequate number of trained staff, a sufficient inventory of spare parts and components to keep systems up and running, preventative or routine maintenance, and unplanned maintenance. Routine maintenance includes tune-ups, tracking unit warranties, ensuring cables and hoses are in a good state of repair, and periodic component replacements.

3.4.3 Lack of Funding for Renewal or Replacement of Systems

Due to age, capacity, or design incompatibility, older ground power and PCA systems and their related components may no longer satisfy the needs of aircraft that they are intended to support. Also, due to market demand changes, airlines are more often using larger aircraft that require higher capacity systems or smaller regional jets that require 28-volt connections instead of 400 Hz systems. To encourage utilization, systems must be sized appropriately to accommodate the varying needs of airlines. The needs of airlines often change over time based on consumer demand and fleet renewal. Budget constraints, planning processes, uncertainty about future fleet mix, or other reasons may prohibit airports—or other system owners—from replacing or upgrading equipment, as needed.

3.4.4 Lack of Electric Ground Power or PCA at Remote Aircraft Parking Positions

Aircraft use hardstands for loading and unloading passengers or for remain-overnight parking positions at various airports. Often, these remote parking positions are not equipped with electric ground power or PCA due to their distance from the terminal or their incompatible location of existing electrical infrastructure and the costs associated with running electric cable to these locations. Therefore, aircraft at hardstands or remain-overnight positions use mobile, fossil fuel-powered PCA and GPUs, if available; or they use APUs. Depending on how often hardstands or remain-overnight positions are used, the emissions associated with the use of aircraft APUs or mobile units could be significant.

3.4.5 Gate Electrification Equipment Not Individually Metered or No Ability to Track Utilization at Individual Gates

The lack of monitoring and tracking capabilities can inhibit utilization as it prevents the airport and airline from gaining an understanding of historic and real-time utilization rates. Without individual electrical or hour meters and/or sensors on equipment, airports and airlines cannot accurately track equipment use to ascertain the utilization (i.e., the amount of time the equipment is available for use to an aircraft parked at the gate versus the amount of time the equipment is actually in use with APUs off). Without accurate data, stakeholders may experience difficulty identifying patterns and determining possible causes of suboptimal utilization.

3.5 Climatic Factors

Staff from airports in a range of climate zones were interviewed and surveyed for this project. Regardless of their geographic location, they all reported that climate and weather factors impact utilization of gate electrification equipment.

3.5.1 Ambient Temperatures Exceed the Design Limits of PCA System

One of the most frequently cited challenges (from all stakeholders) that prevents utilization of electric PCA systems is when ambient temperatures are too hot for the PCA to effectively cool the aircraft. The same holds true for airports located in colder climates, where ambient temperatures may get too cold for PCA to effectively heat the aircraft (although this problem is not as frequently reported by stakeholders as temperatures that are too hot for PCA to be effective).

PCA systems are designed to condition air to a temperature, humidity level, and air flow rate suitable for passenger comfort and safety within the aircraft cabin. In cases of extreme hot or cold ambient outdoor conditions, the intake air may exceed the design limits of the PCA system, meaning that the system cannot overcome the differential between the intake air temperature and the specified delivery air temperature and volume (rate) into the aircraft. For example, ambient ramp air temperature of 110°F is beyond the capabilities of some PCA systems to cool to a temperature (e.g., 68°F) that will satisfy existing airline customer service standards for cabin air temperature. Since pilots are responsible for maintaining passenger comfort and safety, they often choose to augment PCA in these circumstances with onboard aircraft air-conditioning systems, which are powered by the APU.

Interviews with airline and airport staff revealed that APU utilization is virtually continuous during periods of the year in which the ambient ramp air temperature exceeds the design limits of PCA systems, which may reflect conditions spanning upwards of 3 months or more. All airlines use a variety of ways to maintain adequate aircraft cabin temperatures while minimizing APU use. However, these methods are not effective for prolonged periods of either high-temperature days or low-temperature days. While system owners and maintenance providers cannot control the climate, systems should be designed, sized, and maintained to accommodate typical climatic conditions.

3.5.2 Unsafe Weather Conditions Preventing Ground Crew Working on Ramp

Thunderstorms (i.e., lightning) or other unsafe weather conditions may prevent ground crew from connecting ground power and PCA systems to the aircraft, resulting in the necessity for pilots to start and/or leave the APU running. This challenge affects airports throughout the U.S., although it is of greater significance at airports that experience frequent summer thunderstorms, such as those in the Southeast and Great Plains.

3.6 Policy and Regulatory Factors

This category of challenges refers to policy decisions or regulatory constraints that may affect gate electrification system use at airports.

3.6.1 Short Aircraft Turn Times Precluding Use of Gate Electrification Systems

Airlines often direct pilots to use APUs while at an aircraft parking position if the time spent servicing an aircraft between flights (i.e., turn time) is shorter than a specified time (e.g., 30 to 45 minutes), as determined by an individual airline's state of repair. Since airlines must ensure that flight schedules remain on a precise timetable, short turnaround times may not warrant sufficient time to connect and disconnect the aircraft to gate electrification systems. If the PCA and ground power equipment are not designed in a way that facilitates a quick deployment and storing, then misuse or accidental damage (e.g., hoses or power cables that are heavy and cumbersome to move and position properly) may be more likely.

3.6.2 Lack of a Regulatory Driver or Policy Requirement

None of the U.S. airport staff interviewed or surveyed for this project mandate that airlines use PCA and ground power when such equipment is available, although a few airports have policies encouraging the use of these systems. Zurich International Airport in Switzerland was the only airport interviewed for this project with a requirement that airlines use PCA and ground power (when available) in lieu of APUs.

There may be a greater incentive for airports to implement policies that encourage or require—when feasible—the use of gate electrification systems (and for airlines to consistently use these systems) if the airport is located in NAAQS nonattainment or maintenance zones, is subject to state air quality regulation, or if the airport has ambitious air quality and greenhouse gas emissions reduction goals. Conversely, there may be less of an emphasis on the strict use of gate electrification systems for airports located in regions that have not had problems with poor air quality or have not faced political or community pressure to address air quality.

Growing awareness of the environmental benefits of these systems—in addition to the economic benefits associated with reduced fuel use and less APU maintenance—strengthens the airline argument that use of these systems should be encouraged or required.

3.7 Identification of Challenges at Individual Airports

A self-assessment checklist was developed by the research team to assist airports and airlines in identifying the specific challenges to gate electrification system use at their sites. The checklist is intended to serve as a high-level screening tool for users to assess the challenges that have the greatest relative impact on use and to assist users in determining the relative level of effort (i.e., time and resources) required to address each challenge. The tool is contained in an accompanying Excel spreadsheet available for download. Detailed instructions for its use are included on the first tab.

3.7.1 Self-Assessment Checklist

The Self-Assessment Checklist is not intended to identify every possible barrier or challenge to utilization, given the wide range of variables across airports in the U.S. However, it does

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provide a starting point for assessing the 19 most commonly identified challenges, described in previous sections. The checklist includes default ratings for both the relative significance of each challenge (i.e., how much of an impact it may have on system utilization) and the relative ease of addressing each challenge.

The default settings were selected based on feedback obtained from airports, airlines, pilots, and equipment manufacturers during the research. These ratings are relative, as there are not enough data available on actual utilization rates to determine specific impacts that individual challenges have on overall system use. In addition, the actual resources required to address each challenge will vary by airport. Users of the tool may change these settings for each challenge (by clicking on the drop-down list in each cell) to better reflect the situation at their airport.

Column E of the spreadsheet contains the default rating for how impactful the challenge is to gate electrification system utilization (in relation to the other challenges). This rating can be changed based on the unique situation at the airport in question. Users can select ratings from the drop-down menu in each cell.

Column F of the spreadsheet contains the default rating for how resource-intensive each challenge is to address in relation to other challenges. This rating can be changed based on the unique situation at the airport in question. Users can select ratings from the drop-down menu in each cell.

Challenges that are both highly impactful and least resource-intensive to address are listed at the top of the checklist and are color-coded accordingly. Challenges that have the greatest relative potential to impact the use of gate electrification systems are colored green. Those challenges with potential to have a moderate impact are colored yellow. And those with the least potential impact on use are colored red.

Likewise, challenges that are least resource-intensive to address are color-coded green. Moderately resource-intensive challenges are yellow. And those that are likely to require the greatest resources to address are colored red. Challenges get simultaneously less impactful to utilization and more difficult to address the further down the checklist. Again, these ratings will vary from airport to airport.

Column G of the spreadsheet allows users also select the relative significance of each challenge—very significant, moderately significant, least significant, or not a challenge—to the individual gate, terminal, or entire airport from the drop-down menu. These ratings are also color-coded as green, yellow, red, and gray, respectively. Items rated as “not a challenge” and colored gray can be removed from consideration.

Once the checklist is complete, the user will be able to easily identify those challenges that have the greatest potential impact on gate electrification system use and are least resource-intensive to address (i.e., items that are colored green in Columns E, F, and G).

The items that are highly impactful and require the least amount of resources should be addressed before challenges that are less impactful and more difficult to address (yellow or red).

The first tab of the checklist document, labeled “Read Me First—Instructions,” provides more detailed instructions for use, as well as an explanation of the type of information contained in each column and the color-coding system.

The information in the checklist can be used to guide conversations with other stakeholders—airports, airlines, maintenance providers, equipment manufacturers, and ground crews—about gate electrification equipment utilization. Figure 13 depicts a screenshot of the first three challenges listed in the checklist.

ACRP 02-76 Airport Self-Assessment Checklist							
Challenge #	Challenge Title	Category	Description	Relevant Importance to System Performance and Utilization	Relative Level of Effort to Address (time, cost, complexity of challenge)	User Self-Assessment (how significant is this challenge for you?)	Potential Solutions (numbered as listed in Guidebook Section 4)
1	Ground crew non-compliance with airline standard operating procedures (SOPs)	Training and Communications	Most airlines have established maximum allowable times for ground crews to connect both ground power and PCA systems to aircraft upon arrival at the gate (for example, within 5 or 10 minutes of aircraft arrival at gate). If ground crew do not connect aircraft in a timely manner, pilots are likely to start and leave the APU operating for the duration of time they are parked at the gate. A quick connection is imperative, particularly for aircraft with short "turn times" (i.e. the time an aircraft arrives at a gate to when it departs).	high	low level of effort / cost / time		1, 3-6, 8, 12
2	Improperly positioned PCA Hose (i.e. hose kinks)	Operation of Equipment	A fold, or kink, in a PCA hose can impede air flow to the aircraft, resulting in insufficient heating or cooling of the aircraft cabin. Pilots will turn on the APU if the PCA cannot keep aircraft cabin temperatures comfortable for passengers. Hose kinks result from ground crew failure to deploy the proper length of hose (for example, if too much hose is deployed, kinking is more likely), or ground crew do not ensure that hoses are laid flat when deployed. Hoses can also become kinked when they are not stored properly. Over time, frequent kinking of the hose may result in permanent damage to the component, requiring replacement.	high	low level of effort / cost / time		4-9, 11-13
3	Damaged Ground Power Cables and/or PCA Hoses	Operation of Equipment	Ground power cables and PCA hoses can become damaged through normal wear and tear, but also as a result of improper use. These consumable items are essential to providing power and conditioned air to the aircraft. If either of these items are not in good operating order, pilots are likely to start and/or leave the APU running. For example, if power cable heads are dropped repeatedly or dragged across the ramp area, the cable heads and connecting pins may become bent or broken, rendering the cable inoperable. PCA hoses can tear or rip if repeatedly dragged across pavement. In addition, if the items are not retracted and stored properly, they may be subject to damage as a result of being run over by jet bridges or other ground support equipment vehicles on the ramp.	high	low level of effort / cost / time		4 - 13

Figure 13. Example Self-Assessment Checklist.



CHAPTER 4

Solutions to Address Utilization Challenges

Actions—or solutions—to address the challenges described in Chapter 3 were identified during this research project through discussion with airports, airlines, pilots, and equipment manufacturers. The solutions are organized into high-level categories that correspond closely with those used to organize the challenges in Chapter 3 and include: 1. Stakeholder Engagement, 2. Operation of Equipment, 3. Maintenance of Equipment, 4. Resource Allocation, 5. Climatic Factors, and 6. Data Collection and Automation.

The solutions are organized into the categories based on the predominant type of action described in each solution (Table 2). In addition, each solution may address challenges in more than one category. For example, Solution 2: Convene meeting for stakeholders to discuss data sharing, is included under the Stakeholder Engagement category. But it can be effective at addressing operations and maintenance-related challenges, as well.

The solutions are further categorized as “near-term” or “medium- to long-term” actions. This distinction reflects the relative level of effort expected to implement each solution. For example, within the Stakeholder Engagement category, Solution 1: Identify and utilize existing opportunities to discuss status of gate electrification equipment, is a near-term action that can be implemented quickly (and without the expenditure of significant staff or financial resources). In contrast, Solution 3: Convene stakeholders to review performance and develop improvement action plans, is an action that likely requires more resources and greater coordination between stakeholder groups and, therefore, has a longer expected implementation timetable.

The numbering of solutions is for identification purposes (to assist users in matching challenges with solutions) and not an indication of priority or importance.

Most of the solutions do not include information that assigns responsibility to specific stakeholder groups for implementation. Many solutions may be implemented by more than one group at a given airport, depending on the ownership structure of the equipment, airport–tenant relationship, lease terms, and the role of third-party service providers, among other factors.

4.1 Stakeholder Engagement

Communication between stakeholders is important to facilitate gate electrification system utilization. Communication between ground crews and the maintenance providers, as well as between ground crews and pilots is essential for ensuring awareness of system availability, for example. Lack of effective communication between these parties with regard to broken or malfunctioning equipment and subsequent notification when service has been restored can result in confusion and suboptimal system use. Lack of effective communication from ground crews to pilots with regard to system availability may result in pilots choosing to start and/or leave the APU operating.

Table 2. Solutions to address utilization challenges.

Solutions to Address Utilization Challenges		
Solution Category	Number	Solution Description
Stakeholder Engagement	1	Identify opportunities to discuss status of gate electrification equipment during existing meetings of stakeholders to raise awareness.
	2	Convene a meeting for airport and airline stakeholders to discuss enhanced data sharing.
	3	Convene stakeholders to review performance and develop improvement action plans.
Operation of Equipment	4	Verify operator's (ground crew) knowledge of established airline standard operating procedures and policies with regard to use of ground power and PCA.
	5	Verify that operator's (ground crew) training is effective and frequent enough to ensure the proper and safe handling and storage of systems and equipment.
	6	Reduce variability in ground crew training regimens and airline policies to enhance consistency.
	7	Verify individual operator's knowledge and competence in identifying and reporting damaged or inoperable equipment to appropriate stakeholders.
	8	Employ technologies to track an individual operator's use of the gate electrification equipment to enhance accountability.
	9	Provide visual cues on proper use and storage of equipment and system status.
	10	Obtain ground crew verification of the aircraft ground power receptacle serviceability.
	11	Develop an operational performance (or compliance) report identifying findings of knowledge, competence, training, and staffing levels of operators.
	12	Develop standard training video(s) or computer-aided instruction for equipment operators.
	13	Install equipment designed to address common operational challenges.
Maintenance of Equipment	14	Verify maintenance provider's knowledge and competence in performing established manufacturer maintenance standards.
	15	Adhere to a preventative maintenance program.
	16	Maintain comprehensive maintenance records.
	17	Share maintenance records or reports with additional stakeholder groups, such as airlines, airport finance and leadership, or other stakeholders, as appropriate.
	18	Maintain critical spare parts inventory.
	19	Ensure dedicated maintenance personnel coverage at all times.
	20	Implement policy to visually tag out-of-service equipment.
	21	Verify the serviceability of the aircraft ground power receptacle.
	22	Complete a maintenance audit of existing gate electrification systems, equipment, and critical spare parts inventory.
	23	Review adequacy of seasonal changeover dates for central PCA systems.
	24	Verify that actual maintenance personnel staffing is in accordance with established staffing levels.
	25	Consider implementing automated means of identifying, tracking, reporting, and sharing maintenance data and equipment status.
Resource Allocation	26	Foster airport and airline collaboration to identify and address staffing shortages.
	27	Create a capital development program, and identify funding sources to allow for renewal, replacement, and right-sizing of gate electrification equipment.
Climatic Factors	28	Review airline actions to maintain adequate aircraft cabin temperature when ambient air temperature exceeds the design limits of the PCA system.
	29	Develop policies and procedures to ensure safety while minimizing ramp closure time in the event of inclement environmental conditions (e.g., danger of lightning strike during electrical storms).

(continued on next page)

Table 2. (Continued).

Solutions to Address Utilization Challenges		
	30	Design and procure PCA systems that enable redirection of conditioned air from the aircraft to the jet bridge.
	31	Research methods to enable use of air diverted from the passenger terminal as the intake air for the PCA system.
	32	Design and procure PCA systems considering projected climate and weather data to account for climate change.
Data Collection and Automation	33	Establish gate electrification equipment utilization tracking program.
	34	Convene meeting of stakeholders to review existing software systems and sensors or other technologies that could enable the automated tracking and reporting of system utilization.

Regular communication between airlines and pilots with regard to corporate policies on APU use and follow-up communication when anomalies are detected can increase prioritization of gate electrification system use. Finally, opening lines of communication between airport and airline stakeholders with regard to gate electrification system use, data needs, and availability can lead to more collaborative approaches to improving utilization.

4.1.1 Near-Term Solutions

1. Identify and utilize existing opportunities to discuss status of gate electrification equipment.

Consider adding the discussion of gate electrification equipment status and utilization issues as a standing agenda item to monthly station manager meetings and other local airport stakeholder meetings. This discussion will raise awareness among stakeholders of system availability, equipment that experiences frequent maintenance issues, scheduled or unexpected repairs, replacement timelines, and so on.

2. Convene a meeting for airport and airline stakeholders to discuss enhanced data sharing.

This proposed action can help relevant stakeholders (i.e., operations and maintenance departments, information technology system personnel, and tenant airlines) understand what data are currently being captured with regard to gate electrification use, availability, and reliability. It will also identify data that airlines are collecting with regard to APU use while at gates equipped with electric PCA and ground power. The purpose of such a meeting (or meetings) is to:

- Jointly determine strategies to facilitate data sharing across stakeholder groups to better support critical decision making relevant to achieving higher utilization;
- Identify current challenges with regard to system utilization that would benefit from more deliberate sharing of existing information, and establish procedures for sharing these data sets;
- Identify immediate actions that could be implemented to automatically capture and share data from existing gate electrification systems. These actions may include installing metering equipment, adding and activating sensors to system components, establishing a common electronic data repository, and expanding data access to additional authorized users to broaden data consumption; and
- Evaluate existing software platforms currently in use by stakeholders that could be altered or upgraded to more effectively capture, report, and disseminate data across the trusted stakeholder groups.

4.1.2 Medium- to Long-Term Solutions

3. Convene airport and airline stakeholders to review performance and develop improvement action plans.

Once existing opportunities to share information and data have been identified and implemented, airports may consider convening all relevant stakeholders to collaboratively review related items that the data may help inform. These items may include existing system and equipment utilization data, airline policies and state of repairs with regard to equipment use, training curriculums, staffing standards, and communication protocols. The purpose of this activity would be to assess how each stakeholder group can:

- Refine existing programs and practices to improve utilization;
- Develop more efficient and effective training and familiarization programs;
- Develop more effective personnel hiring practices and performance qualification standards; and
- Streamline approaches to tracking, reporting, and sharing information to effectively address challenges as they arise while using existing personnel and systems.

4.2 Operation of Equipment

As discussed in Chapter 3, a majority of airports and airlines interviewed and surveyed for this research project reported that operator error or misuse of equipment is a factor that affects gate electrification utilization. Accidental damage to equipment by operators results in equipment being out of service for repair and, therefore, unavailable to aircraft. The actions described in this section address these operational challenges.

4.2.1 Near-Term Solutions

4. Verify individual operator's (ground crew) knowledge of established airline standard operating procedures and policies with regard to use of ground power and PCA.

Depending on the ownership arrangement of gate electrification equipment and the entity providing ground services, this action could be accomplished by the airport, airline, or third-party contractor, as appropriate. The entity undertaking this action should obtain the relevant airline state of repairs for connecting aircraft to equipment and the equipment manufacturers' instructions for use, including any manufacturer-specific state of repairs. The simplest way to implement this action is to observe actual performance of ground crew in the field, including recording the time it takes to complete the tasks—such as connecting aircraft to PCA and ground power equipment—and noting whether equipment is used and stored properly. If undertaking an observational study, observers should consider the effect of their presence on the performance of ground crew (i.e., if staff are aware that an observer is evaluating their performance, they may alter their behavior in response).

The objective of this activity is to ensure that individual ground crew personnel and supervisors demonstrate knowledge and competence in connecting aircraft to gate electrification equipment, as per established airline policies and manufacturer guidance (e.g., within a specified period of time after aircraft arrive at the gate). If operators are not complying with airline and equipment manufacturers' state of repairs, the ground crew training program content and instructions should be reviewed to ensure that they are in accordance with existing policies and guidance.

5. Verify that operator's (ground crew) training is effective and frequent enough to ensure the proper and safe handling and storage of systems and equipment.

During the research for this project, airports and airlines frequently reported high ground crew turnover as a challenge to ensuring adequately trained personnel. Airports and airlines can review the content and frequency of training—including new-hire training and refresher training for existing staff—to determine if it is adequate to ensure an effective and knowledgeable ground crew, taking into consideration the rate of employee turnover. This solution includes actions to:

- Verify that training program course content and instructions are in accordance with manufacturer-defined proper and safe operation and handling of systems and equipment;
- Collaborate with equipment manufacturers and installers to provide live training—on site at the airport or at a manufacturing facility—to airport and airline ground handling personnel; and
- Implement “train the trainer” instruction in which there are one or more certified on-site trainers responsible for training new personnel as designated trainers, enabling basic familiarization.

If a local training program, such as “train the trainer,” has been established, airport and airlines should verify that the training program course content and instruction is in accordance with manufacturers’ requirements for current equipment (i.e., in the event that any PCA or ground power equipment has been upgraded or modified since the training program was developed).

The gate electrification equipment owner (typically the airport) can bring equipment manufacturers on site to provide periodic training, as well. In some cases, airport staff provide some training to ground handlers to reinforce proper procedures for using PCA and 400 Hz ground power equipment. For example, Denver International Airport staff trains one to two staff from each airline on the proper operation of equipment, occasionally arranging for equipment manufacturers to provide additional training. The airlines are then responsible for training their own ground crews, resulting in a consistent and well-trained ground crew.

Once the proper training content, delivery mechanisms, and frequency have been established, the airport and airline(s) should update state of repairs to include this guidance and ensure that it is being implemented (e.g., through performance reviews).

6. Reduce variability in ground crew training regimens and airline policies to enhance consistency.

Third-party companies that provide contracted ramp services to multiple airlines at an airport are often required to comply with multiple airline state of repairs, resulting in training challenges. Communication and coordination between the ground services provider, airlines, and the airport to standardize training requirements and system operation can result in more consistent and aligned procedures being provided to ground crews serving more than one airline. This consistency, in turn, minimizes the chance of operator error or lack of compliance. The resulting consistent state of repairs can be written into contracts between the service provider and the airline (or airport).

7. Verify individual operator's knowledge and competence in identifying and reporting the status of damaged or inoperable equipment to appropriate stakeholders.

The airport or airline can determine if individual ground crew personnel demonstrate knowledge of proper reporting procedures to communicate damaged or inoperable equipment to the airline operations staff and appropriate airport stakeholders. This determination can be accomplished through observation of practices, review of maintenance

requests (e.g., identify who made requests, when requests were made, and whether duplicate requests were made), or by interviews with individual operators. Ground crew supervisors should reinforce the importance of following established reporting procedures when directing staff. Prompt reporting of damaged equipment enables maintenance providers to address the problem and return equipment to service more quickly.

8. Employ technologies to track an individual operator's use of the gate electrification equipment to enhance accountability.

This action can be accomplished through the installation of digital equipment locks with individual employee keys, passcodes, or key cards required to use the equipment. This solution allows for more accurate assignment of responsibility for operation of the equipment, correlates component use with possible damage, and increases awareness of individuals using the equipment. Similar technology may also make it possible to disallow equipment use for operators who have not been trained. It also enables the system owner or maintainer to resolve maintenance costs and seek reimbursement from the tenant responsible for damage, when warranted.

9. Provide visual cues on proper use and storage of equipment and equipment availability.

The airport or airline can consider installing placards that depict the proper position to connect equipment such as cables, hoses, and so on to the aircraft, as well as the proper storage of such equipment between uses. For example, placards that instruct ground crew not to use the emergency shut-off switch on equipment can be prominently displayed.

The airport or airline could also include the gate electrification equipment status on the ramp information display system. Pilots will be able to see the status of the equipment in real time, which should minimize miscommunication resulting in APU use (Figure 14).



Figure 14. Typical ramp information display system (Source: Frederick Roe, ADB Safegate).

10. Obtain ground crew verification of the aircraft ground power receptacle serviceability.

Ground crew must ensure that the ground power cable head has been properly connected to the aircraft and that the ground power unit is energized and operating. If the connection is verified but the aircraft does not receive ground power, the ground crew should notify the appropriate contact (airport operations or maintenance department) of the situation, following local maintenance service request protocols.

The maintenance service request should also include a test of the aircraft power receptacle serviceability to determine whether there is a problem with the aircraft's ability to accept ground power. If airline maintenance staff or approved parties verify that the individual aircraft's power receptacle serviceability is in working order and a problem manifests itself on a subsequent aircraft using that gate, then a problem may exist with the electric ground power equipment. In this case, ground crew should notify the maintenance provider and request an immediate test of the ground power equipment.

4.2.2 Medium- to Long-Term Solutions**11. Develop an operational performance (or compliance) report identifying findings of knowledge, competence, training, and staffing levels of operators.**

Based on findings from solutions involving verification of knowledge, competency, and training programs for equipment operators, the airport—or other appropriate stakeholders, such as the airline or contractor providing ground power services—may develop a comprehensive report that summarizes results to create an action plan that addresses identified deficiencies. The report could be used to convene a meeting of all stakeholders to focus on systemic issues that were identified and justify additional budget requests to address remedial training, staffing shortages, or other issues that have an impact on system utilization.

12. Develop standard training video(s) or computer-aided instruction for equipment operators.

Computer-aided and/or video-based instruction could be provided by the equipment owner on the proper operation and storage of gate electrification equipment to all operators, regardless of which airline or company they serve. For example, many airlines provide their state of repairs on training software that automatically enrolls all personnel into required training classes and then records when the employee has successfully completed their assigned training. Stakeholders may consider collaborating on the development of a computer-aided training course or video to include content on the importance of prioritizing gate electrification equipment over APUs when available, as well as best practices for operating systems and safeguarding equipment. One airline interviewed for this research project reported using videos to train ground crew and emphasize the importance of using gate electrification equipment from an environmental and fuel-saving standpoint. The research did not uncover examples of collaborative approaches to producing training videos for all operators at one airport.

13. Install equipment designed to address common operational challenges.

As discussed in Chapter 3, operator error is a common occurrence that can negatively impact system utilization. Equipment manufacturers have developed and improved products to help combat some common issues, such as PCA hose kinks and cable damage. Examples include:

- PCA hose reels that dispense more accurate lengths of hose needed (to prevent excess hose from gathering on the ramp), which reduces the risk of kinks and prevents the hose from getting run over by a jet bridge or ground support equipment (Figure 15);



Figure 15. *Twist Aero's Boom-Air Hose Management System (left). ITW GSE PCA hose reel with extension reels (right) (Source: Twist Inc. and ITW GSE).*

- Hose extensions for servicing aircraft with the PCA connector located near the rear of the aircraft (Figure 15);
- In-ground storage of power cables to prevent components from being run over and damaged (Figure 16);
- Ground cable hoists and cable head stands to ensure that cables are properly stored prior to jet bridge operation, as well as to preclude cables from being run over;
- Equipment with start-stop controls that are intuitive and prominent to avoid the use of emergency stop buttons; and
- Insulated hoses that minimize the loss of cooled or warmed air along the length of the hose as air is delivered to aircraft.



Figure 16. *400 Hz ground power underground pit system (Source: Fleuti and Ruf 2018).*

4.3 Maintenance of Equipment

Systems and equipment must be adequately maintained to ensure availability and reliability and, thus, achieve optimal utilization. A number of maintenance solutions and best practices were identified through stakeholder engagement conducted throughout this research project. Although airport staff typically maintain these systems, in some cases third-party service providers—either contracted by the airport or airline—or equipment manufacturers provide maintenance services. The following actions can be considered by appropriate stakeholders to address maintenance-related challenges.

4.3.1 Near-Term Solutions

14. Verify maintenance provider's knowledge and competence in performing established manufacturer maintenance standards.

The airport or other appropriate stakeholder can assess individual maintenance personnel to ensure that they demonstrate knowledge and competence of gate electrification equipment maintenance standards in general and any systems that are unique to the individual airport. If a local training program has been established (e.g., train the trainer), the airport or stakeholder responsible for maintenance of systems should verify that the maintenance staff training program course content and instruction is in accordance with the manufacturer's requirements and, if necessary, provide manufacturer training programs to new hires and periodic refreshers for existing maintenance personnel.

15. Adhere to a preventative maintenance program.

Like other equipment, ground power and PCA components should be inspected and maintained according to a regular preventative maintenance schedule to avoid operational failure. Preventative maintenance programs consist of planned activities at set intervals designed to prolong the useful life of equipment. Preventative maintenance and quality control practices are intended to resolve problems before they lead to equipment malfunction. Most airports interviewed for this project reported having a preventative maintenance program in place for gate electrification equipment. And some airports reported performing quarterly maintenance, in addition to annual, comprehensive, preventative maintenance of their units. Preventative maintenance on jet bridges and gate electrification system components can be completed at night and during off-peak hours to minimize time out of service.

In addition, maintenance providers should consider the use of retrofit devices intended to decrease maintenance needs for aging PCA systems (e.g., a screen or filter outfitted to prevent PCA hose insulation from entering the aircraft air duct should insulation separate from the hose during normal wear).

16. Maintain comprehensive maintenance records.

Comprehensive maintenance records enable staff to identify problems that result from accidental damage to and misuse of the gate electrification equipment, compared to equipment failure for other reasons (e.g., equipment that reaches the end of its useful life). Accurate historical system-specific maintenance data are useful for ensuring that spare parts are stocked on site when possible, while providing additional context concerning the expected life span of various equipment. Periodic review of maintenance logs and work orders yields insight into expected useful life of the equipment and assists with long-term planning for equipment replacement, staffing levels, and budgeting. In addition, sharing maintenance reports and records with other stakeholders may raise awareness of system availability and provide justification for the replacement of equipment or stockpiling of spare parts, for example. Computerized maintenance

management systems (CMMS) can help manage records and are discussed in more detail in Solution 25.

17. Share maintenance records or reports with additional stakeholder groups, such as airlines, airport finance and leadership, or other stakeholders, as appropriate.

Maintenance departments that collect and maintain extensive maintenance data should find a means to summarize, communicate, and share this information with other relevant stakeholders within and outside of their organization. Data transparency may lead to additional support for maintenance efforts, while providing baseline data to other stakeholders to inform budgeting and investment decisions. For example, airlines can work with airports as partners to advocate for appropriate maintenance contracting, ground crew staffing, system-renewal schedules, and so on if they have access to data that demonstrate the age and reliability of systems at the gates they use. A CMMS can also assist with the dissemination of maintenance records to multiple stakeholders.

18. Maintain a critical spare parts inventory.

Airports that maintain an on-site critical spare parts inventory for PCA and ground power equipment can restore systems to working order quickly without waiting on spare parts to ship from off-site locations. A number of factors—such as the current or planned consumption rate of components, failure rates, and costs—should be considered when estimating appropriate inventory levels. The procurement process required for replacement parts, combined with the shipping time for their arrival on site, leads to preventable delays in maintenance and extends the time that the gate electrification system is out of service. These delays result in the need for pilots to run onboard engines to maintain passenger comfort at the gate. Airports may consider maintaining backup mobile ground power and PCA units in stock to use while repairs are being made if spare parts are unavailable. It is even more critical to maintain spare parts for older equipment due to decreased availability of parts or of units no longer in production by manufacturers, which leads to additional delays in bringing equipment back into service.

19. Ensure dedicated maintenance personnel coverage at all times.

Insufficient staff availability and prioritization of maintenance of gate electrification systems can result in extended critical system outages. Ensuring that dedicated maintenance teams—those with specific knowledge of the gate electrification systems—are on site during main operational hours or on call for off-peak hours to service PCA and ground power systems leads to consistency and reliability of systems and minimizes down time. Major maintenance work on gate electrification systems required to adhere to preventative maintenance programs can be completed by a specialized maintenance team at night or during off-peak hours to avoid daytime disruptions to operations.

20. Implement policy to visually tag out-of-service equipment.

Maintenance staff should perform regular equipment inspection using a checklist of all system components and visually tag any equipment that is out of service to allow for easy visual identification of equipment status by all parties. This allows for targeted maintenance responses and elimination of redundant maintenance action requests while increasing awareness as to when equipment is back in service (as the tag will be removed after repair).

21. Verify the serviceability of the aircraft ground power receptacle.

Airlines should regularly use test devices that verify the serviceability of aircraft ground power receptacles, which serve a similar purpose as test devices used by ground service equipment maintenance personnel but on the cable head side (e.g., go/no-go gauges and load bank). Alternatively, airlines could consider permitting airport maintenance personnel to use an airline-approved test device to verify the serviceability of the aircraft ground power

receptacle to mitigate potential cases of ground power connection failure due to faulty aircraft ground power receptacles.

If a receptacle is found to be faulty, airlines should request notification of this outcome, along with the tail number of the aircraft to alert their aircraft maintenance staff of the faulty receptacle and to schedule repair of the receptacle.

22. Complete a maintenance audit of existing gate electrification system(s) and equipment.

A maintenance audit (commonly referred to as a “spot check” program) is intended to evaluate overall existing maintenance practices and procedures, including work order tracking, spare parts inventories, staffing levels, and ordering systems compared to prescribed procedures and practices. An audit helps identify opportunities for improvement. The results of a maintenance audit should be reported to relevant stakeholders and can serve as a basis for the request of supplemental funding, if appropriate. Funding may be required to address any existing backlog of outstanding work orders (i.e., to provide augmented staffing, overtime, and repair parts acquisition). The maintenance provider can request a meeting with stakeholders to address systemic issues identified in the audit.

23. Review proposed winter and summer central PCA system changeover dates in advance of conducting future changeovers.

Centralized PCA systems are often programmed to switch from heating to cooling in conjunction with seasonal changes, rather than being readjusted daily. This adjustment often results in aircraft running APUs during shoulder seasons when the ambient temperatures are less predictable and there is greater variability between temperature swings throughout a 24-hour period, providing less predictability from day to day. This uncertainty often results in a mismatch between the PCA output temperature and the needs of the aircraft. Airports and airlines should coordinate a review of seasonal weather patterns to come to a consensus on changeover dates and further determine if the central PCA system can be modified to allow more flexibility in adjusting temperatures to respond to aircraft needs. In addition, airports should confirm that they provide advanced notification of the changeover date to airlines to ensure communication to pilots of the local airport situation with regard to the availability of PCA.

4.3.2 Medium- to Long-Term Solutions

24. Verify that actual maintenance personnel staffing is in accordance with established staffing levels.

The equipment owner or maintenance provider should verify that maintenance staffing levels are sufficient to provide timely repair of gate electrification equipment. This information may be one of the outcomes of the maintenance audit. If maintenance staffing levels are not adequate, additional actions include:

- Determining the appropriate level of staffing to enable prompt attention to repairs of gate electrification equipment and systems;
- Collaborating between airport operations, maintenance, and human resources departments—others as appropriate—to evaluate recruiting and hiring practices, and implementing necessary changes to keep pace with actual staff turnover rate; and
- Determining whether salaries, benefits, and advancement opportunities are sufficient to encourage staff commitment and reduce staff turnover rate.

25. Consider implementing automated means of identifying, tracking, reporting, and sharing of maintenance data and equipment status.

Some airports have obtained or designed equipment capable of automatically uploading information from gate electrification systems into the airport’s CMMS. These systems are

valuable for observing whole system operability and quickly identifying any maintenance needs. Maintenance and technician history can also be held in the CMMS, and equipment audits can be obtained. Additional information on CMMS can be obtained through the *ACRP Web-Only Document 23: Guidance on Successful Computer Maintenance Management System (CMMS) Selection and Practices*.

4.4 Resource Allocation

The provision of sufficient resources, including staff and funding, is required not only to acquire and install gate electrification equipment but to ensure that it is right-sized for the aircraft using it, well maintained, reliable, and promptly replaced when it reaches the end of its useful life.

4.4.1 Near-Term Solutions

26. Foster airport and airline collaboration to review resource (staffing and funding) needs.

While airports do not have control over airline staffing budgets, staff levels and airline commitments can help inform investments by the airport. This action can take the form of a meeting between the airport finance department, other airport departments (such as operations, maintenance, planning, engineering, and human resources), and the airlines to review existing staffing levels and operating budgets. Review will help to determine whether staffing and budgets are adequate, as well as determine capital projects required to ensure the availability of gate electrification systems. Stakeholders should identify appropriate funding levels for staffing and equipment acquisition, system operation, and maintenance, and identify funding mechanisms necessary to address near-term solutions to challenges identified during the review process.

4.4.2 Medium to Long-Term Solutions

27. Create a capital development program and identify funding sources to allow for installation, renewal, replacement, and right-sizing of gate electrification equipment.

The design, acquisition, and installation of electric ground power and PCA systems represent a significant expense for airports, regardless of whether FAA VALE funding—or other grant programs—are available. The airport and airlines should discuss the current and forecasted airline gate needs to develop appropriate long-term funding and development plans for associated gate electrification equipment, which necessitates the involvement of airport finance, planning, and engineering departments.

This action also includes the consideration of the costs and benefits associated with providing electrical power infrastructure to remote aircraft hardstands that are used for overnight parking, as well as for scheduled flight operations served by passenger busing operations. Mobile, electric (battery-powered) GPUs can be considered as an interim solution for providing clean power to aircraft parked at remote hardstands, which are less costly than construction associated with running electrical conduit to these locations.

4.5 Climatic Factors

While airports and airlines cannot control the weather, there are some measures that stakeholders can take to mitigate certain impacts that weather and climate have on system use.

4.5.1 Near-Term Solutions

28. Review airline actions to maintain adequate aircraft cabin temperature when ambient air temperature exceeds the design limits of the PCA system.

Some airlines reported taking steps to maintain comfortable aircraft cabin temperatures when ambient temperatures are very warm or very cold to minimize APU use when possible. These actions include:

- Raising or lowering cabin temperature prior to arrival at the gate to compensate for the loss of conditioned air upon opening the aircraft for deplaning and servicing;
- Requesting that passengers lower all cabin window shades and open the air vents above their seat prior to deplaning; and
- Providing air curtains at aircraft doors used by aircraft catering or cabin cleaners, which minimizes the loss of conditioned air while aircraft is being serviced.

29. Develop policies and procedures to ensure safety while minimizing ramp closure time in the event of inclement environmental conditions (e.g., danger of lightning strike during electrical storms).

Airports and airlines can collaborate to ensure consistent policies and procedures with regard to the conditions that provoke ramp closures. They should also include information for ground crew about when it is safe to reopen the ramp after an event. In regions where it is warranted, stakeholders might consider adoption of systems that sense the potential for lightning. These systems have been deployed by airports and airlines to provide greater precision in detecting hazardous conditions. They serve as a feasible solution, since they allow for timely ramp evacuation, as well as efficient restoration of ramp operations.

4.5.2 Medium to Long-Term Solutions

30. Design and procure PCA systems that enable redirection of conditioned air from the aircraft to the jet bridge.

This is a system design solution to ensure that sufficiently cooled and conditioned air is immediately available to an arriving aircraft during periods of high ambient temperatures. Essentially, a diverter redirects the conditioned air from the PCA hose into the jet bridge to provide additional jet bridge cooling between aircraft operations. The diverter enables the crew to disconnect the PCA hose from a departing aircraft (at pushback) without turning off the PCA system, particularly when the next aircraft has arrived and is waiting to pull into the gate.

Once the first aircraft has departed and the second has arrived, the PCA hose is then attached to the arriving aircraft and conditioned air is redirected through the PCA hose. Conditioned air is immediately available to the arriving aircraft, which results in pilots avoiding use of the APU.

This type of system is currently being tested by at least one airline, which has informally reported that the system is effective at keeping aircraft cool up to ambient temperatures of 110°F. However, this type of system may not be appropriate or feasible to implement at all airports (i.e., airports located in mild climates may not find this necessary). System owners may undertake a cost-benefit analysis to determine if this type of system is a feasible solution.

31. Research methods to enable use of air diverted from the passenger terminal as the intake air for the PCA system.

Most PCA systems use outside air for intake. When ambient temperatures are either very hot or very cold, PCA systems may not be sufficiently powerful (i.e., right-sized) to effectively heat or cool the intake air required for the system, which often comes directly

from the ramp area. The possibility of using conditioned air from passenger terminals as the intake air for PCA systems should be explored, as such air is already conditioned and well within the intake air temperature design limits of the systems. This type of system modification (i.e., recirculation configuration) requires further examination to determine its feasibility, air quality impacts, and conformity with National Fire Protection Association (NFPA) codes and standards. A cost–benefit analysis could determine the potential cost savings, saved APU operating hours, and air emissions benefits.

32. Consider projected future climate and weather in the design and procurement of PCA systems to account for climate change.

Airports, airlines, and equipment manufacturers should consider projected future climate and weather patterns to account for climate change when determining the type and size of PCA equipment needed. For example, the hottest 4 years on record have occurred since 2014 (World Meteorological Organization 2018). If stakeholders only rely on historical weather data when determining the required heating and cooling load, then the system may not be able to handle future heating and cooling needs.

4.6 Data Collection and Automation

A lack of data with regard to gate electrification equipment use can contribute to a knowledge gap among stakeholders pertaining to the impact of various factors on utilization rates. This gap, in turn, can impede efforts to address challenges and often prevents the optimization of system utilization.

4.6.1 Near-Term Solutions

33. Establish a gate electrification equipment utilization tracking program.

Airports or airlines can begin monitoring and reporting gate electrification use to develop an understanding of current utilization rates and changes over time. This assessment will assist stakeholders in determining the effectiveness of various solutions on improving utilization. This effort can be accomplished using the basic Utilization Tracking Methodology described in Chapter 5, in conjunction with the accompanying Excel spreadsheet or by other means, depending on airport resources and capabilities (specifically, if airports have technology in place to capture use data). To begin tracking utilization, some or all of the PCA and ground power equipment must be equipped with hour meters.

4.6.2 Medium- to Long-Term Solutions

34. Convene meeting of airport and airline stakeholders to review existing software systems and sensors that could enable automated tracking, reporting, and dissemination of system utilization data.

This solution involves collaboration among stakeholders to evaluate the benefit of retrofitting or augmenting existing gate electrification systems and software platforms—such as building automation systems or CMMS—to track equipment utilization and availability. For example, Seattle–Tacoma International Airport’s central PCA system data were integrated into the airport’s existing building automation system through a custom software interface developed in coordination with the equipment manufacturer. This integration allows the airport to monitor the PCA equipment status and use in real time, enabling staff to quickly identify problems and better adjust the PCA system components to meet operating conditions and needs of aircraft. This capability allows the airport to monitor multiple

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components of the system, such as system mode, air temperature, ambient temperature, and gates that have equipment in use, among other variables. In addition, Seattle–Tacoma International Airport is pilot testing ADB Safegate SafeDock automated docking systems at some gates, which can be used to track the amount of time aircraft are at each gate and, thus, enable the airport to understand overall PCA and ground power utilization rates better. Further details with regard to Seattle–Tacoma International Airport’s system are described in Section 6.13.

Stakeholders can collectively evaluate the costs and benefits of acquiring such capabilities when gate electrification equipment and systems are replaced or upgraded. Conversations with stakeholders will help to further evaluate the feasibility and effort associated with integrating various systems in the airport environment.

CHAPTER 5

Utilization Tracking Methodology

The majority of airports interviewed for this research project report that they do not systematically track the utilization rates of their gate electrification systems. Airports that received VALE grants for the purchase of gate electrification equipment do track its use for reporting emissions reductions. However, their focus is to determine the amount of emissions avoided; not on the percentage of time gate electrification equipment is actually used compared to what is possible. The VALE program requires that airports track equipment use to calculate estimated emissions savings from that equipment's deployment. For example, an airport that acquired electric PCA and/or ground power equipment with a VALE grant may record the use of this equipment through an hour meter. This information would then be correlated with the type of aircraft that used the equipment to determine the reduction in emissions from the use of gate electrification equipment compared to the use of a jet fuel-powered APU.

While this information is helpful, it does not necessarily provide the airport or airline with an understanding of the utilization rates of gate electrification equipment. Information gathered as part of the VALE program does not provide insight into the amount of time the equipment was used compared to the amount of time it could have been in use (see Section 5.1 for additional details).

Other than tracking gate electrification equipment use for estimating emissions reductions for VALE grant compliance, airports have mainly focused on ensuring that the equipment is available for use by airlines (i.e., installed and maintained).

Airports and airlines are now jointly striving to reduce the emissions footprint of APUs, as well as ensuring adequate aircraft cabin cooling and heating to address passenger needs. To facilitate these goals, and to receive the return on investment for system costs, there is a shared desire to increase utilization of gate electrification systems. Therefore, this report includes a basic example Utilization Tracking Methodology. The benefits of tracking utilization include: 1. Assists stakeholders to better understand their system's performance and utilization for benchmarking and compilation of data, 2. Enables stakeholders to identify conditions when equipment is not used and associated barriers to use to facilitate improvement, and 3. Enables stakeholders to verify that environmental objectives are achieved.

The example methodology described in this chapter is designed to serve as a starting point for airports to estimate utilization rates of their gate electrification equipment. The accompanying Excel file can be used to calculate a basic utilization rate, or the airport can modify the spreadsheet to include additional information to suit their needs.

The methodology is partially based on FAA VALE program reporting requirements, specifically with regard to tracking equipment use. The methodology also incorporates some of the same assumptions included in the *FAA VALE Program Technical Report*, Version 7, with regard

to minimum APU use per turn and temperature ranges for PCA use. The intent in incorporating these elements is to maintain consistency with FAA guidance and to take advantage of information that some airports already have on hand.

5.1 Methodology Background

The example Utilization Tracking Methodology is provided to assist owners and operators of electric PCA and ground power systems to calculate system utilization rates. The basic methodology developed for this ACRP project is designed to be simple and requires minimal technology and staff resources. It is also designed to be easily implemented by airport staff with little existing data. The methodology and accompanying Excel file will allow users to generate a reasonable estimate of electric PCA and ground power utilization at their facility.

For the purposes of this methodology, utilization is defined as the percentage of time that available equipment is actually in use divided by the maximum amount of time it could be used. The maximum amount of time that equipment could be in use is calculated in the steps below and takes into account variables such as number of turns per gate, average time per turn, APU use, and temperature.

$$\text{Utilization} = \frac{(\text{average hours per day equipment is actually in use})}{(\text{average total hours per day the equipment could be in use})}$$

The methodology allows users to calculate utilization rates for ground power systems and PCA systems separately, by individual gate, by terminal, or by a combined rate for the entire airport.

The methodology includes averaging, and it incorporates an assumption with regard to the minimum amount of time that aircraft need to use the APU per gate turn (i.e., 7 minutes per turn, according to the *FAA VALE Program Technical Report*, Version 7). It does not require the user to determine actual APU use, as that would likely require the installation of more sophisticated technology and/or the acquisition of data from airlines that are not readily available.

For these reasons, the utilization rates obtained with the application of this methodology should be regarded as reasonable estimates and not precise rates. The estimates can be used to track an airport's system utilization over time for that individual airport. Given the range of variables—weather, climate, percentage of gates equipped with PCA and ground power, airline activities and policies, maintenance practices, and so on—that can affect PCA and ground power utilization from location to location, one airport's estimated utilization rates should not be compared to other airports' rates.

The example methodology requires that users have information on the run time—or hours of use—for both PCA and ground power equipment. This information can be obtained from hour—or run-time—meters installed on individual pieces of equipment. (These are not electrical meters, which record kilowatt hours of electricity use.) In many cases, PCA and ground power equipment already have these devices installed; if not, the equipment can be retrofitted relatively easily at a low cost.

If hour meters are not installed on equipment at every gate, this approach may still be used to track utilization. If hour meters are only available on some pieces of equipment, the airport operator will simply calculate the estimated utilization rate for those pieces of equipment that have hour meters. Pieces of equipment that do not have meters can be retrofitted should the airport operator wish to obtain a more precise estimate of overall utilization. The accuracy of

the estimates obtained through the use of this methodology will increase as the percentage of gates monitored also increases.

If the gate electrification equipment with hour meters is the same type or model as equipment without meters, and if the equipment is similar in age, it may be reasonable to scale up the estimated utilization rates across the entire airport. However, simply extrapolating the utilization rates obtained from a few gates to the whole airport may not be a reasonable approach if the nonmetered equipment is different, older, requires more maintenance, or is otherwise out of service for a longer time.

Likewise, the Excel file can be modified if the airport has additional data that they would like to include. For example, a column can be added to provide space for the user to enter information about the specific type or model of PCA and ground power equipment at each gate. Section 5.1.1 contains instructions on how to unprotect the worksheets for modification.

5.1.1 Worksheet Formulas and Protection

The accompanying Excel file has a number of formulas built into the file to simplify the calculations and data entry process. Each worksheet, or tab, is protected, and cells with formulas are locked to prevent accidental edits or deletion of the formulas. However, for users who wish to add rows to record data for additional gates or terminals, change default settings in cells with formulas, or copy or delete whole worksheets, the file may be unlocked. To do so, follow the steps below:

- Click on the “Review” tab at the top of each worksheet.
- Click “Unprotect Sheet.”
- When prompted, **enter passcode 1234** to unlock the worksheet.

To lock an unprotected worksheet, the user should follow the same steps, but select “Protect Sheet” as the second step. Users can input the same passcode to lock the worksheet or enter a new passcode of their choosing.

Before the user enters any data into the highlighted columns, cells that are programmed with a formula may appear to have the following text “#DIV/0!”. This is not an error message; those cells will repopulate once data have been entered by the user into other fields.

The Excel file tab labeled “Example Sheet” is not protected. Users are encouraged to explore this worksheet and change data, add columns or rows, or delete unwanted columns or rows to familiarize themselves with the worksheet and how the outputs change when different data are entered.

5.1.2 Worksheet Labels

Worksheets labeled “Period 1” through “Period 4” only contain space for 400 Hz ground power use. The final worksheet on the spreadsheet, labeled “Period 1 (incl. 28VDC)” includes a column for 28 VDC (volts direct current) ground power use, as well as for those airports wishing to track both.

The references to specific columns in the following steps refer to worksheets labeled “Example,” “Period 1,” “Period 2,” “Period 3,” and “Period 4.” The worksheet labeled “Period 1 (incl. 28VDC)” has two extra columns in the ground power section to account for 28 VDC utilization. Therefore, column letters on that worksheet do not exactly match those in the other worksheets, as described in the following instructions.

5.2 Methodology Instructions

The following sections provide step-by-step instructions for calculating the PCA and ground power utilization rates. The steps describe which information the user should enter into the accompanying Excel file. Columns highlighted in yellow in the worksheets are the fields that require the user to enter data. Columns L and R provide space for the user to enter the amount of time that equipment is out of service at each gate. These fields are optional and are, therefore, not highlighted yellow.

Step 1. Determine the reporting period(s).

It is recommended that users identify a simple reporting period of a week or a month. This will enable the user to quickly become familiar with how to collect data, how to use the methodology, and how to analyze the results. Once familiarized, the user can develop more defined reporting periods for answering specific comparative analysis questions (e.g., if the user wants to compare utilization rates of gate electrification equipment in summer versus winter).

A reporting period is the length of time over which data are collected and averaged. In general, a week is a reasonable time frame over which to collect data, as this reporting period should capture both peak and off-peak travel times, business travel (weekdays), and leisure travel (weekends). A week of data collection is also relatively more manageable from a staff resources perspective than a longer reporting period. The user should decide if shorter or longer reporting periods would be more useful, depending on the user's needs and the comparative analysis questions that the user is attempting to answer.

Since one of the more frequent challenges to PCA utilization reported by airports and pilots occurs when ambient temperatures exceed the PCA system design standards (e.g., ambient temperatures are either too hot or too cold for the PCA to effectively condition aircraft cabins), it may be important for users to select multiple reporting periods to examine utilization rates during different seasons (see Section 3.5 for a discussion on climatic factors affecting utilization). Another factor to consider when selecting a reporting period may include whether the airport experiences distinct high and low seasons for passenger traffic. If so, an airport may wish to examine utilization at multiple periods when passenger traffic and number of operations differ significantly.

The accompanying Excel file contains worksheets for four reporting periods by default: Period 1, Period 2, Period 3, and Period 4. Users should determine whether fewer or more reporting periods are most appropriate to meet their needs. If the user does not need all the worksheets, extra worksheets can be left blank. If more worksheets are needed, they can be copied to create additional reporting periods.

Step 2. Select terminals and gates to be included.

Ideally, all electric GPUs and PCA units are equipped with hour meters and can be included in the analysis. If this is not feasible, the user should select a variety of gates to be monitored. The selection may include gates with differing equipment types, age, and models, as well as airline use and gate configuration. For example, if different types of PCA and ground power equipment are installed (or equipment varies in age), the user should select gates representing each of the various types to ensure a comprehensive review. Likewise, if some terminals have exclusive use gates for one or more airlines and other terminals are mixed use, the user should include both types of gates.

This methodology is designed to provide the user with a basic understanding of utilization rates at the airport. In general, the more gates and equipment that are monitored, the more accurate the estimates of utilization. However, once the user has completed simple analysis,

the data can be used to perform other comparative analyses to identify the root causes of differing utilization rates across airlines and equipment in a given reporting period. For example, if utilization rates show significant differences at gates with identical equipment but are served by different airlines, the airport operator could further investigate the effect of different airline practices and policies on utilization.

Terminals and gates to be monitored should be entered into Columns A and B of the accompanying Excel file, respectively.

Each of the worksheets in the Excel file is built with space for 10 gates at three terminals. Users can leave rows blank if monitoring less than 10 gates per terminal or less than three terminals. Users can also add more rows if more than 10 gates are to be monitored per terminal or if more than three terminals will be monitored.

If the user is monitoring more than 10 gates in a given terminal, follow this process to add rows:

- Click on the “Review” tab at the top of each worksheet, and then click “Unprotect Sheet.” When prompted, **enter 0276** to unlock the worksheet.
- Select Cell A13 on sheet “Period 1” and right-click the mouse. Select “Insert.” Then select “Entire Row.”
- Once the new row(s) has been added, highlight the entire Row 14 and right-click the mouse. Select “Copy.”
- Select the blank row above, right-click the mouse, and select “Paste.” Repeat as necessary until the desired number of rows has been added.

Step 3. Determine average number of daily operations for each gate.

For each gate included in the monitoring process (listed in Column B of the Excel file), determine the average number of daily operations (or turns) (i.e., aircraft serving that gate during the reporting period). For example, if the reporting period is one week, the number of operations per gate per day should be recorded and then averaged over the week. This number should be entered into Column C for each gate. Many airports already collect gate block time, which can be used, or these data can be obtained from airline schedules.

This methodology does not require the user to determine the number of operations by type of aircraft (i.e., narrow body, wide body, jumbo jet, or regional jet) or by specific APU models, as one might do when developing emissions inventories. Although this information is important for understanding the environmental benefits of gate electrification equipment, the intent of this methodology is to be a starting point for determining utilization rates. While utilization rates at some airports may be influenced by aircraft type, collecting these data is not crucial to this particular exercise.

Step 4. Determine average amount of time aircraft are at gates.

The next step is to determine the average amount of time aircraft remain at each gate per turn (i.e., departure time minus arrival time). If possible, the user should determine actual turn times to increase accuracy. If this information is not available, the default time per turn used in the FAA Aviation Environmental Design Tool 2d—26 minutes for both wide-body and narrow-body aircraft—can be used.

Turn times should then be averaged for each gate over the reporting period and entered (in minutes) into Column D. For example, if the reporting period is 1 week, the turn times per day should be recorded and then averaged over the week.

Columns E through H will automatically populate once data have been entered into Columns C and D, but each step is described as follows.

Step 5. Calculate the average amount of time per day, in minutes, that aircraft are at each gate.

This number is calculated by multiplying the average number of daily operations per gate by the average amount of time (in minutes) that aircraft are at each gate per turn. The resulting number is the average total time per day (in minutes) that aircraft are at each gate. This information will automatically populate in Column E.

Airport operators may wish to calculate a weighted average utilization rate if some gates have significantly more operations than others. However, the accompanying Excel spreadsheet does not automatically do this.

Step 6. Calculate the minimum APU run time per gate.

The minimum APU run time per gate is obtained by multiplying the average number of turns per day (Column C) by 7 minutes. The *FAA VALE Program Technical Report*, Version 7, uses a default assumption for the minimum amount of time an aircraft APU must be used during gate-in and gate-out operations of 7 minutes. Since this is also the value used by airports for VALE reporting purposes and because actual APU use data are more time- and resource-intensive to gather, the methodology uses the 7-minute default figure, as well. This information will automatically populate in Column F.

If the user has actual APU use time available, those data can be included for each gate in Column F instead of the default time of 7 minutes per turn. To include these data, the user should first ensure that the worksheet is unlocked (follow steps in Section 5.1.1). Then, the user should enter the amount of time that aircraft APUs were in use at each gate during the reporting period (total APU use during the reporting period divided by number of days in the reporting period).

Step 7. Calculate the maximum amount of time (in minutes) per day that electric PCA and ground power could be in use by aircraft.

This is calculated by subtracting APU run time per day (Column F) from amount of time per day aircraft are at each gate (Column E). PCA and ground power are generally not needed when APUs are in use, so the amount of time APUs are in use (Column F data) is subtracted from the total amount of time aircraft are at the gate. This information will automatically populate in Column G.

Step 8. Convert Column G to hours.

Convert the maximum amount of time PCA and ground power systems could be in use from minutes to hours by dividing the number of minutes in Column G by 60. This information will automatically populate in Column H.

Step 9. Determine average daily time (in hours) ground power equipment is in use.

For each gate listed, data from the hour meters on the electric ground power equipment should be recorded at the beginning and at the end of the reporting period. The number on each meter at the beginning of the reporting period should be subtracted from the number at the end of the reporting period to get the total number of hours the ground power equipment was in use (for each selected gate). That number should be divided by the number of days in the reporting period to get the average number of hours the ground power equipment was in use per day. This number should be entered into Column I.

The total average daily hours that ground power equipment was in use for each terminal will automatically populate (the gray rows).

Step 10. Review utilization rate for ground power equipment.

The utilization rate for 400 Hz ground power (or both 400 Hz and 28 VDC) at each gate will automatically be calculated in Column J. The utilization rate is calculated by dividing the hours

of actual ground power use (Column I) by the maximum time ground power equipment could be used (Column H). The average utilization rate for all gates in a given terminal will appear in the last row of that section (in the Example worksheet, the average utilization rate for Terminal A appears in Cell J14).

Column K provides the weighted utilization rate based on number of operations per gate. This information will calculate automatically. The utilization rate for gates with a higher number of turns per day will be weighted proportionally more than the utilization rates of gates with fewer operations. This column is not useful on a per gate basis but is important for the terminal as a whole. In the Example worksheet, Cell K14 contains the adjusted utilization rate for Terminal A. The Example worksheet shows a slightly higher ground power utilization rate in Cell K14 compared to the unadjusted rate in Cell J14. This accounts for the high utilization rates for Gates A7 and A8 being weighted more heavily, given their higher number of daily operations.

Step 11. Determine percentage of time ground power equipment was out of service.

Column L is optional, but it can be used to help interpret utilization rates. If the airport—or equipment maintainer, if other than the airport—has sufficient maintenance data available to determine the approximate percentage of time the ground power equipment was out of service (due to maintenance needs, replacement, and so on), the data should be entered in Column L. The user can then compare utilization rates by gate (or terminal) to the percentage of time the equipment was unavailable for use due to maintenance needs. While these two variables are not always correlated, they do provide a starting point for airports or equipment users to investigate possible causes of low utilization.

Step 12. Determine the percentage of time that cooling or heating is needed.

Aircraft heating and cooling is not needed at all times. FAA assumes that aircraft heating is necessary when ambient temperatures are below 45°F, and cooling is needed when temperatures are above 50°F (FAA 2010). Therefore, the maximum amount of time that electric PCA systems are needed to provide heating and cooling is dependent on the weather.

Users should determine the percentage of time during the reporting period that ambient temperatures were either below 45°F or above 50°F and enter that figure as a whole number into each row in Column M. If the airport uses a different temperature range for determining heating and cooling modes, the airport-specific range should be used instead of the default temperature range.

If the PCA system provides ventilation during periods when neither heating nor cooling is needed, then the system might be in use even when temperatures are in the neutral range. In this case, the airport may consider that PCA is needed 100 percent of the time for utilization rate calculation. If so, then the user should enter 100 for each gate in Column M. Another consideration is the frequency of flights when PCA is needed compared to frequency of flights when PCA is not needed. If the airport determines that temperatures during the study period necessitate PCA use consistently during the times of day when flights are most frequent, and if flights are relatively infrequent during times of day when PCA is not needed (such as at night), then the airport may wish to enter “100” for each gate in Column M, recognizing that for the majority of flights PCA is needed 100 percent of the time, based on weather. Alternatively, airports may wish to set up two study periods: one during times of day when temperatures necessitate the use of PCA and one during times of day when temperatures are within the neutral range.

Although the percentage of time that temperatures warranted either heating or cooling will be the same for all gates, it must be entered into each row for the formula in the adjacent column to work properly.

Weather data can be obtained from the National Oceanic and Atmospheric Administration National Weather Service or from airport records.

Step 13. Calculate maximum amount of time electric PCA could be used, adjusted for temperature.

Next, for each row (i.e., for each gate) users should multiply the data in Column H (the maximum number of hours per day that electric PCA and ground power equipment could be used) by the percentage of time heating or cooling was needed during the reporting period (Column M). This information will be automatically calculated in Column N of the Excel file.

Step 14. Determine average daily time electric PCA equipment is in use (in hours).

For each gate listed, data from the hour meters on the electric PCA equipment should be recorded at the beginning and at the end of the monitoring period. The number on each meter at the beginning of the recording period should be subtracted from the number at the end of the recording period to get the total number of hours the PCA equipment was in use (for each selected gate). That number should be divided by the number of days in the recording period to get the average number of hours the PCA equipment was in use per day. This number should be entered into Column O by the user. The total average daily hours that PCA equipment was in use for each terminal will automatically populate (the gray rows).

Step 15. Review utilization rate for electric PCA equipment.

The utilization rate for electric PCA equipment will automatically be calculated in Column P. The utilization rate is calculated by dividing the hours of actual PCA use (Column O) by the maximum time PCA equipment could be used (Column N).

Column Q provides the weighted utilization rate based on number of operations per gate. This information will calculate automatically. The utilization rate for gates with a higher number of turns per day will be weighted proportionally more than the utilization rates of gates with fewer operations. This column is not useful on a per gate basis, but it is important for the terminal as a whole. In the Example worksheet, Cell Q14 contains the adjusted PCA utilization rate for Terminal A. The Example worksheet shows a slightly higher PCA utilization rate in Cell Q14 compared to the unadjusted rate in Cell P14. This accounts for the high utilization rates for Gates A7 and A8 being weighted more heavily, given their higher number of daily operations.

Step 16. Determine percentage of time PCA equipment was out of service.

Like Column L, Column R is optional, but it can be used to help interpret utilization rates. If the airport—or equipment maintainer, if other than the airport—has sufficient maintenance data available to determine the approximate percentage of time the PCA equipment was out of service (due to maintenance needs, replacement, and so on), the data should be entered in Column R. The user can then compare utilization rates by gate (or terminal) to the percentage of time the equipment was unavailable for use due to maintenance needs. While these two variables are not always correlated, they do provide a starting point for airports or equipment users to investigate possible causes of low utilization.

5.3 Next Steps

The Excel-based tool allows users to catalog existing data to better understand and improve utilization of gate electrification systems. The tool is based on metrics and methodology available in the *FAA VALE Program Technical Report*, Version 7, and may assist operators in pinpointing high-level faults in their system; thus, enabling them to improve system reliability. The tool can also provide a general understanding of gate electrification system availability. System

availability is a function of both reliability (time between failure) and maintainability (average time necessary to make repairs); thus, representing the percent of time that units are available for use by aircraft.

Once utilization rates have been obtained for multiple reporting periods, the rates can be compared and tracked for internal benchmarking purposes. The utilization rates for ground power and PCA for multiple reporting periods can be combined to estimate an average annual utilization rate, for example. Anomalies can be further examined to determine what may be causing higher or lower utilization at different gates during different times of the year, based on maintenance records and so on. The methodology is intended as a starting point for discussions between airports and airlines, system owners, maintainers, and operators to determine how to improve overall utilization.



CHAPTER 6

Airport Case Studies

In this chapter, 15 airport case studies are presented. The case studies appear in alphabetical order by city name. The airports selected for the case studies were chosen to encompass a broad range of sizes, geographic locations, and climate zones, as ambient temperatures have been identified as a significant contributing factor in the use or non-use of electric PCA systems at airports.

Figure 17 depicts a U.S. climate zone map (boundaries shown are by state and county), as described in the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 169-2013 Climatic Data for Building Design Standards. To demonstrate the climatic differences between zones, the graph in Figure 18 displays the annual heating and cooling degree days per climate zone. A degree day is defined as “the difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature.” For example, the higher the number of cooling degree days (CDD), the warmer the climate is in that zone. The higher the number of heating degree days (HDD) the colder the climate zone, on average. Generally, a higher number of degree days means that there are more opportunities to condition aircraft air to a comfortable temperature for customers. In these zones, utilization of gate electrification systems is suggested to avoid APU use.

6.1 Hartsfield–Jackson Atlanta International Airport (ATL), Atlanta, Georgia

Background

Hartsfield–Jackson Atlanta International Airport (ATL) is the busiest airport in the U.S., serving more than 103 million total (enplaned and deplaned) passengers in 2017 (Figures 19 and 19A). Hartsfield–Jackson Atlanta was one of the first airports to develop a sustainable management plan under FAA’s Sustainable Master Plan Pilot Program in 2011. The airport’s original sustainable management plan notes that PCA and ground power connections at aircraft parking positions provide an environmentally friendly alternative to running aircraft APUs. At the time the sustainable management plan was written, the airport had equipped 90 percent of their gates with electric PCA and 400 Hz ground power. Currently, 100 percent of the gates are equipped. The airport has both central and point-of-use PCA equipment. Although utilization is not currently tracked, and the gates are not individually metered, the airport is working to identify possible tracking solutions.

While there are almost 30 passenger airlines serving the airport, the majority of market share is accounted for by Delta Air Lines, with almost 74 percent of total passengers (according to the airport’s 2017 December passenger traffic report). Southwest Airlines has the second-highest number of passengers, at just under 10 percent. Gates are leased to the airlines. Although the gate electrification systems are owned by the airport, the airlines are responsible for funding the maintenance, as per the lease terms.

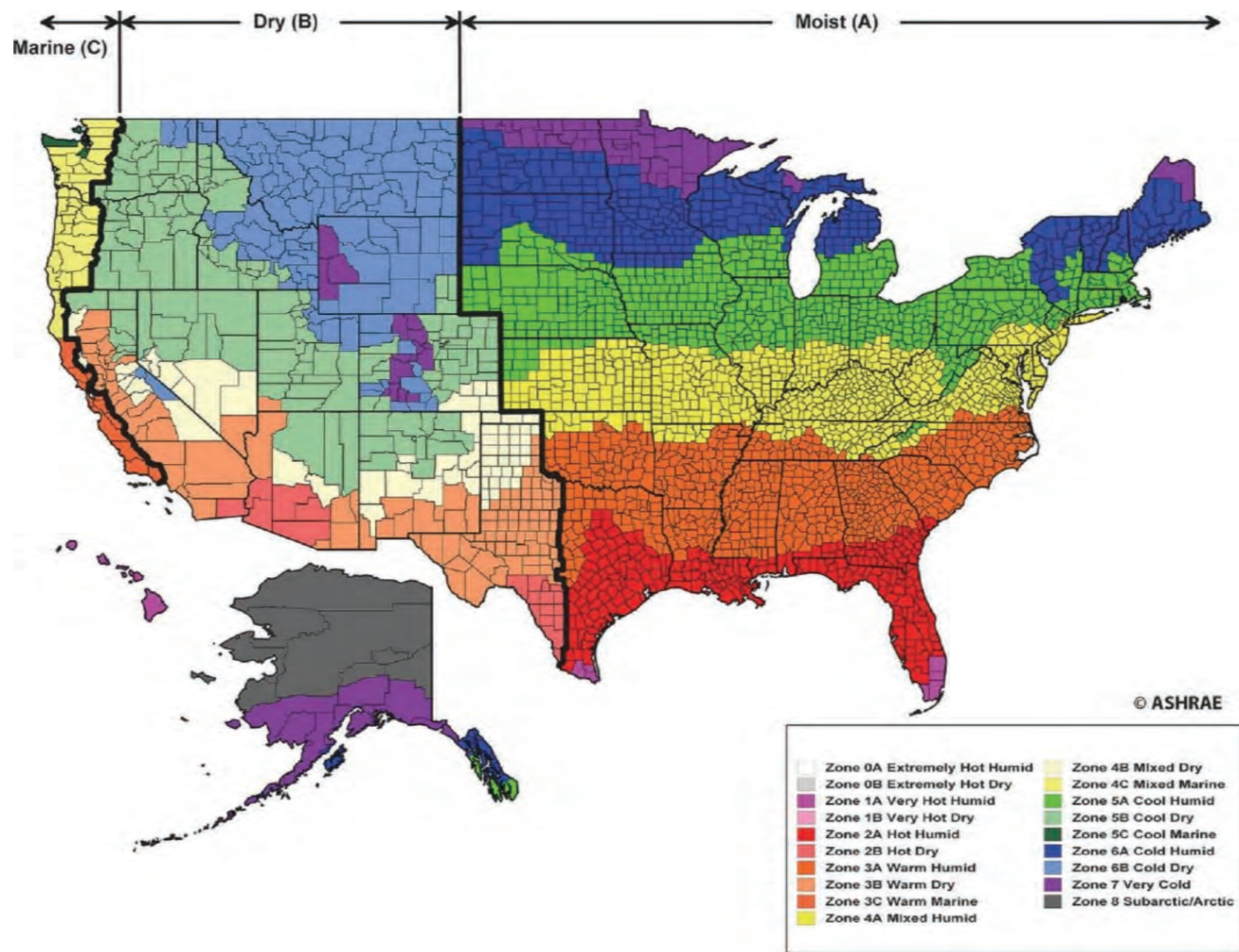


Figure 17. ASHRAE climate zones for U.S. counties (Source: Appendix B, ANSI/ASHRAE Standard 169-2013).

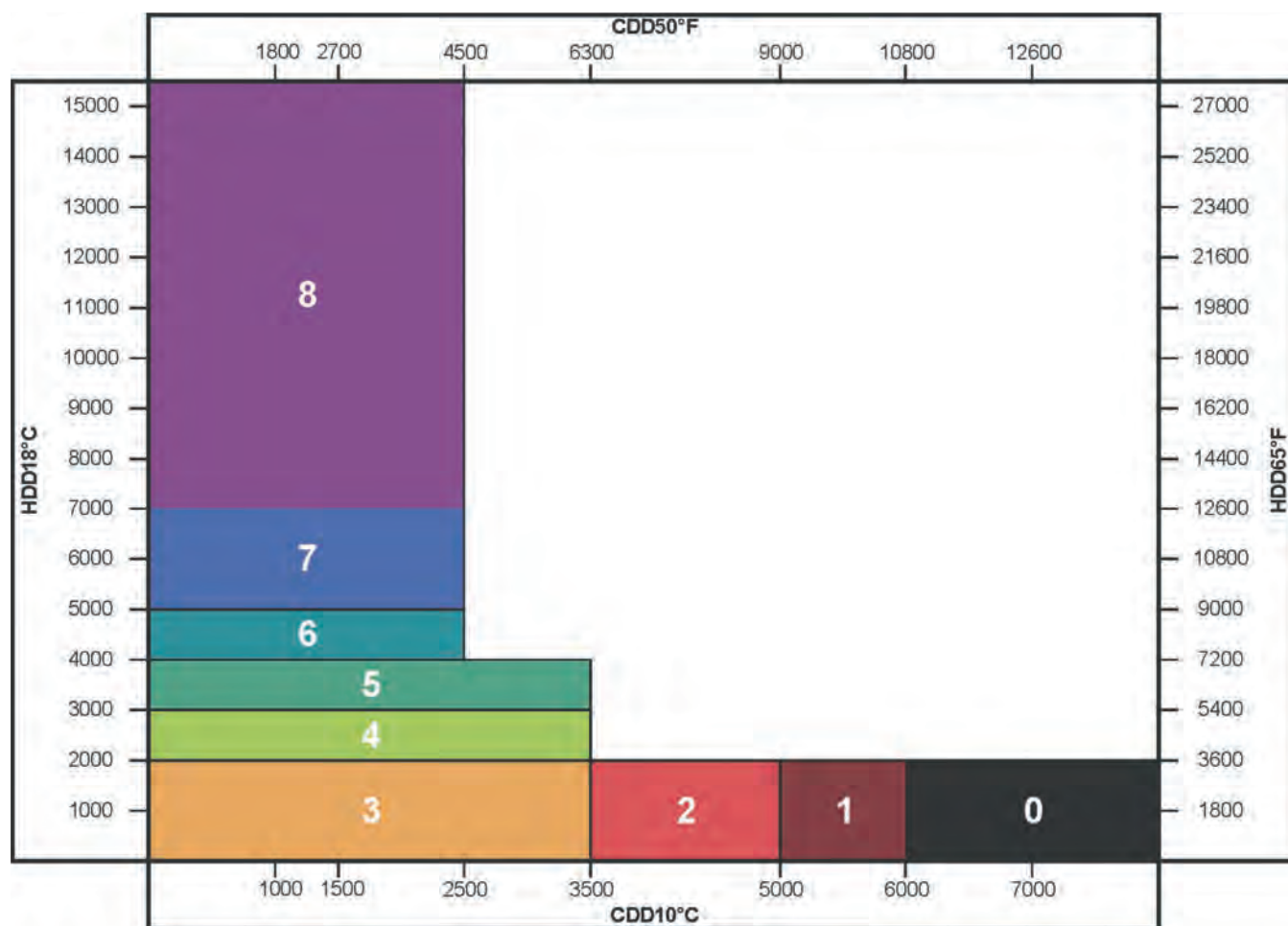


Figure 18. Thermal climate zones as a function of HDD (heating degree days) and CDD (cooling degree days). The colors and numbers in the graph depicted above correspond to the climate zone colors and numbers in the map depicted in Figure 17 (Source: ANSI/ASHRAE Standard 169-2013).

Drivers for Installation

- Decisions on installation are driven by executive staff and airline needs.
- Environmental stewardship is a key driver for installation.

Finance Strategy

- Finance strategy is set by executive staff.
- Gate electrification equipment at Hartsfield–Jackson Atlanta has not historically been funded with VALE grants.

Planning and Policy

- The Atlanta Department of Aviation consulted with airlines to determine specifications for equipment.
- Design and installation of the equipment was a collaborative effort between the Atlanta Department of Aviation, the airlines, and gate electrification equipment manufacturers.
- Maintenance of gate electrification systems is handled by a combination of airport staff, airline staff, third-party service providers, and equipment manufacturers.



Figure 19. Hartsfield-Jackson Atlanta International Airport aerial view.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 2A, Hot/Humid Large hub, primary, commercial - Passengers (total): 103,934,417 - Passenger growth (2016–2017): -0.23% - Cargo weight: 691,269 metric tons - Cargo growth: 6.58% - Number of passenger airlines serving: 29 <i>2017 data provided by the airport</i>	- There are 194 operational gates, all airport owned. - All gates are equipped with electric PCA and 400 Hz ground power. - The airport has both central and point-of-use systems. - There are some airline-owned mobile diesel units. - There are four hardstands that are not in use as of 2018. - Utilization rate is not tracked (electricity use included in concourse power feed).
Major Tenants	Regulatory Issues
- Passenger airlines: Delta Air Lines, Southwest Airlines, and ExpressJet - Cargo: FedEx, United Parcel Service (UPS), and Delta Air Lines <i>Carriers with greatest market share listed</i>	- VALE status: Eligible - Current NAAQS status: Maintenance zone for PM_{2.5} and moderate zone for ozone (8-hour) - VALE participation: VALE grants for compressed natural gas vehicle projects (2012, 2013, and 2014). No gate electrification system components funded through VALE.

Figure 19A. Hartsfield-Jackson Atlanta International Airport specifications (PM_{2.5} refers to particulate matter).

- The airlines are responsible for disseminating any company policies with regard to electric PCA and ground power use to their employees.
- No formal tracking system is in place for tracking maintenance work orders or job prioritization.

Tracking and Data Collection on Utilization

- No utilization data collection system is in place, but the airport is considering options to implement one.
- Gates are not individually metered.
- The Atlanta Department of Aviation has no policies requiring or encouraging the use of gate electrification equipment.

Lessons Learned and Best Practices

- Maintenance staff and ground handling crews are trained on proper equipment use by the equipment manufacturers.
- The building management system is occasionally used to notify carrier and airport staff about equipment outage or failure.
- The majority of gates are leased to one airline, which reduces the variability in ground crew training regimens and airline policies.

6.2 Boston Logan International Airport (BOS), Boston, Massachusetts

Background

At Boston Logan International Airport, all of the 94 operational gates are equipped with electric ground power units, and 87 out of 94 gates are equipped with electric PCA (Figures 20 and 20A). There are a number of remote hardstands in use for both passenger boarding and overnight aircraft parking, which are serviced by gas and diesel powered mobile PCA and ground power units.

While airlines and airport staff report observing high PCA and GPU usage, the weather and climate at Boston Logan create some utilization challenges for PCA systems. Due to the extreme cold in the winter, airlines report that the PCA systems are unable to provide sufficient heat for cabins of certain aircraft models when the outside temperature is below 20°F. In these conditions, the pilots turn on the APUs to maintain passenger comfort. Utilization at Boston Logan can also be impacted by high wind events. During these conditions, operators do not connect to PCA systems and instead use APUs because PCA hoses may become unsecured and lead to safety issues on the apron. Heat during summer months in Boston was not identified as a significant challenge to the use of PCA; however, one airline identified difficulty in maintaining comfortable cabin temperature during summer months for a specific aircraft type due to the location of the air intake.

In general, airline and airport staff reported that electric PCA and GPU utilization is high, despite not having equipment in place to conduct systematic monitoring and tracking (with the exception of VALE-funded equipment, which is monitored to estimate emissions reductions). Utilization seems to be more consistent when airlines have exclusive use of the gate(s) and use in-house maintenance staff. The importance of proper education and training of ground crews, as well as preventative maintenance, was emphasized.

Drivers for Installation

- While regional air quality has improved, consistent community focus on air quality helps drive continuous improvement by Massport and stakeholders.
- In public environmental documents, Massport regularly reports on the air quality benefits of the use of gate electrification systems.
- Emissions reductions realized from installation and use of electric PCA and GPU can eliminate—or reduce—the need to offset emissions of construction projects to comply with the Massachusetts State Implementation Plan for air quality.
- The use of electric PCA and GPU results in reduced fuel use and maintenance costs associated with reduced APU cycles, which helps justify the cost of installation.



Figure 20. Aerial view of Boston Logan International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 5A, Cool/Humid Large hub, primary, commercial • Passengers: 38,412,419 • Passenger growth: 5.9% • Cargo weight: 679,407,977 lbs. • Cargo growth: 10.10% • Growth: 2.6% in total operations • About 40 airlines serve the airport. <i>Statistics reflect 2017 data reported by Massport.</i>	• There are 94 operational gates. • There are 87 gates equipped with electric PCA. • There are 94 gates equipped with electric GPU. • Hardstand operations are serviced by mobile diesel- and gasoline-powered PCA and GPUs. • VALE-funded equipment is tracked for estimating emissions reductions; however, utilization rate is not systematically tracked. • Equipment ownership is mixed.
Major Tenants	Regulatory Issues
• Passenger airlines: JetBlue Airlines, American Airlines, Delta Air Lines, United Airlines, Southwest Airlines, Air Canada, Alaska Airlines, British Airways, and Lufthansa • Cargo: FedEx, Quantem, Swissport, UPS, and Worldwide Flight Services	• Current NAAQS status: Maintenance zone for CO • VALE participation: \$2,000,000 (FY 2013) for PCA and ground power units for eight gates and \$2,000,000 (FY 2018) for 50 electric charging stations for electric ground support equipment. Also received \$5,974,017 for 18 CNG and 36 electric/diesel hybrid buses in FY 2010. • Massport voluntarily publishes annual emissions inventories for criteria pollutants and greenhouse gases.

Figure 20A. Boston Logan International Airport specifications (CNG = compressed natural gas).

Finance Strategy

- Gate electrification equipment ownership is mixed. Some components are owned and financed by the airport; others by the airlines.
- Massport funded the purchase and installation of PCA and GPU equipment for eight gates with a VALE grant. Remaining systems were obtained through a combination of airport capital program funding and airline funding.
- One airline noted that investment in new systems is tied to oil prices, and when fuel prices are high it is easier to justify installation of PCA and GPU equipment.

Planning and Policy

- Massport does not have a formal policy requiring airlines to use gate electrification equipment.
- Airlines that participated in the case study interview reported having their own policies that require the use of gate electrification systems when available (though pilots ultimately have control over when to use the aircraft APU).

Tracking and Data Collection on Utilization

- Due to use of equipment in older buildings without submetering, utilization data for electric PCA and GPU are not systematically tracked; however, annual use data (hours of run time) for electric PCA and GPU equipment purchased with VALE grant funds must be recorded so that emissions reductions can be estimated.
- Some gates are equipped with an electric meter, and Massport plans to install meters when replacing or building new gates. However, there are no plans to retrofit existing gates with meters.
- Some airlines pay for electricity use based on actual use; others pay as part of rates and charges.
- One airline noted that they have an internal reporting requirement with regard to APU fuel use compared to fuel targets. When targets are not met, airline management investigates the contributing factors.
- Some airlines track all maintenance calls via a SharePoint site for each of their gates. The information is evaluated and tracked to determine if the maintenance issue is with the equipment or the aircraft.

Lessons Learned and Best Practices

- One airline reported using LED sensors to measure the temperature of air from the PCA hose output to monitor performance.
- Preventative maintenance and quality control for gate electrification systems and components are useful to address problems before they cause equipment to malfunction.
- Training and communication on equipment operation are critical to combat equipment damage from misuse, particularly related to proper disconnection procedures.
 - When fuel prices were higher, the training and education focus was on quick and correct connection of PCA and GPU, with less focus on proper disconnection.
- Simple technology solutions can address common problems that cause damage and subsequent unavailability of equipment. For example, the use of locking and hooking procedures to secure power cables can help prevent cables and PCA hose reels from being run over.
- Anecdotal evidence suggests that utilization rates are higher on gates that are leased exclusively to one airline. There appears to be an opportunity to increase gate electrification system utilization through development of best management practices and standard operating procedure manuals where gates are not for exclusive use, as in Terminal E.

- Collaboration and coordination between airlines and airports is important in:
 - System design, funding, grant applications, and acquisition decisions;
 - Development of team approaches to operating and maintaining equipment;
 - Reporting on performance and outcomes to address issues, solve problems, and establish new best practices.

6.3 Burlington International Airport (BTV), Burlington, Vermont

Background

Burlington International Airport in Burlington, Vermont, is classified by FAA as a small hub airport, with just under 600,000 enplaned passengers per year (Figures 21 and 21A). There are 11 operational gates, which are owned by the airport, with preferential-use leases for tenants. Nine jet bridges are equipped with electric ground power, but only five are equipped with electric point-of-use PCA units (four are airport owned; one is airline owned). The airport-owned ground power and PCA units are not individually metered and, therefore, utilization is not tracked. There are also two remote, remain-overnight parking positions that are served by airline-owned mobile diesel- or gasoline-powered PCA and GPUs.

Burlington International is located in ASHRAE Climate Zone 6A (primarily cold and humid). According to the National Weather Service Forecast office, the city of Burlington has a mean average January temperature of 18.7°F and a mean average temperature for July of 70.6°F. Overall, the airport reports minimal challenges to utilization presented by extremely cold winter weather, but there are some considerations. For example, airlines serving Burlington International face some challenges with regard to APU use in the winter months, particularly overnight when heating demands of the aircraft can exceed gate electrification equipment capabilities. Also reported to occur periodically, the airport-owned jet bridge wheels get stuck in the snow or on ice on the apron. To address this issue, maintenance staff have implemented a best practice of using covers to protect gate electrification assets and certain parts of the motors from weather. Other best practices include the use of equipment that keeps the PCA hose off the ground while it is being rolled up, which prevents the hose from freezing to the ground in the winter. Keeping the hose off the ramp also slows the loss of heated air (in the winter) and the loss of cooled air (in the spring and summer) to the ramp.

Preventative maintenance and routine maintenance calls are handled internally by airport staff for the airport-owned gate electrification equipment. The PCA equipment is serviced by a third party contracted by the airport. The airline-owned gate is also serviced by a contractor. Due to the age of the systems, spare parts availability is an issue, and there is often a long lead time for replacement parts. In some cases, the original manufacturer no longer makes spare components for the type of units in place, leading to delays in system repair and impacting utilization rates. In general, the airport reports that their maintenance budget is sufficient to maintain systems without stresses on resources.

Communication between the airport and airlines with regard to the status and availability of equipment is somewhat informal but effective. Airlines are required to notify airport operations staff of any issues with the equipment. A work order is then created, and maintenance staff is notified. Once the system is fixed and operational, the airport electricians or third-party contractor will notify airport operations and airlines. The airport strives to communicate the status of equipment directly to airline station managers.

The most common reasons cited for aircraft APU use include when the gate electrification equipment is inoperable, when there is a miscommunication between the airline crew and



Figure 21. Aircraft takeoff at Burlington International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 6A, Cold/Humid Small hub, primary, commercial • Enplaned passengers: 591,558 • Passenger growth: -2.15% • Number of passenger airlines serving: 6	• There are 11 operational gates. • Gates are assigned through preferential-use leases. • Nine jet bridges are equipped with electric GPU. • Five jet bridges are equipped with both electric PCA and electric GPU. • Four PCA units are airport owned; one PCA unit is airline owned. • Diesel-powered mobile PCA carts are used for gates without electric PCA and for two remain-overnight parking positions. • Gate electrification system utilization is not tracked by the airport.
Major Tenants	Regulatory Issues
• Passenger airlines: American Airlines, Delta Air Lines, Frontier, JetBlue Airlines, Porter, and United Airlines • Cargo: Wiggins Airways and FedEx • Fixed-base operators: Heritage Aviation	• VALE status: Not eligible • Current NAAQS status: In attainment

Figure 21A. Burlington International Airport specifications.

ground crew about equipment availability, and when such miscommunication occurs when systems are connected to the aircraft. An example of this miscommunication includes when a ground crew member connects the PCA and GPU but the pilot leaves the APU running, even if the PCA is sufficient to heat or cool the aircraft.

Drivers for Installation

- Airlines were supportive of new gates being equipped with electric PCA and GPU when the terminal was built.
- Community is environmentally aware and was supportive of gate electrification system investments.

Finance Strategy

- Cost of gate electrification equipment was part of the capital project when the terminal was built.
- Most airlines do not pay for electricity based on specific usage, as PCA and GPU equipment is not individually metered. Electricity fees are built into rates and charges.
 - One airline is billed for electricity usage for their own PCA and GPU at one gate.
 - Airlines receive a bill for fuel usage of mobile units.
- As older jet bridges are replaced, they will include both electric PCA and GPUs. However, financing has not yet been determined for the end-of-life replacements.

Planning and Policy

- Airport plans to equip future jet bridges with electrification systems as older ones are replaced.
- One airline reported a company policy that requires the use of electric PCA and ground power, when available, at their gate in place of aircraft APUs. This airline's policy also requires that aircraft be connected to external ground power within a certain maximum time frame after parking at a gate and that external ground power not be disconnected prematurely prior to aircraft departure.

Tracking and Data Collection on Utilization

- Airport-owned equipment is not metered, and utilization data for electric PCA and GPU are not systematically tracked by airport.
- Airline-owned gate equipment is metered.
 - Electricity usage is tracked by monthly kilowatt hours and average kilowatt hours used per day for both the PCA and GPU.
 - Airline reports tracking spikes in electricity usage on extremely hot or extremely cold days or when power is needed overnight.
 - Airlines receive bills for diesel fuel for mobile PCA and GPUs and track total fuel use.
- One airline reported receiving an APU utilization report weekly. The airline aims for a certain maximum amount of time of APU use per aircraft when parked. The airline investigates cases where APU use is higher than expected.
- The airport tracks diesel fuel used in portable units. They have individual bills for diesel and for unleaded fuel purchased from fixed-base operators.

Lessons Learned and Best Practices

- Accurate historical maintenance data on all systems are useful for ensuring that spare parts are on hand, for determining which system components need repair more frequently, and for understanding the expected life span of equipment better.

- If airport electricians cannot identify the cause of a broken GPU, the crew will check whether the system is operable for the next aircraft to verify whether it is an issue with the GPU or if the problem originated at the aircraft connection. If the latter, the airport notifies the airline.
- The ground crews are generally well trained and experience low turnover.
- Airlines perform daily equipment inspection with a checklist, and staff will tag any equipment that is out of service to allow for easy visual identification of equipment status.

6.4 Dallas–Fort Worth International Airport (DFW), Dallas, Texas

Background

Dallas–Fort Worth International Airport is the fourth busiest airport in the U.S. (based on 2017 passenger numbers), with 28 passenger airlines serving more than 67 million passengers, the majority of which were carried by American Airlines (more than 85 percent) (Figures 22 and 22A). The airport has 165 gates, of which 111 are owned by the airport and the remainder are airline owned. All gates have electric PCA and ground power equipment (both central and point-of-use) (Figure 23). A number of gates were equipped with electric PCA and ground power with the assistance of VALE grants. In addition to having very comprehensive environmental and sustainability goals, the airport is located in a NAAQS nonattainment zone for ozone and is motivated to reduce both local air-pollutant emissions, as well as greenhouse gases.

Despite achieving 100 percent equipage of gates, only the newest gates are individually metered with electrical meters. The airport does not have a formal utilization tracking process in place. However, hours of run time are tracked for VALE-funded equipment. Airport staff observations indicate that utilization is generally high, but the airport experiences some challenges with gate electrification system utilization. First, some gates have equipment that is at the end of its useful life, thus, requiring more maintenance and resulting in decreased reliability. Second, some PCA units are not right-sized, which means that they do not have sufficient capacity to condition the aircraft size presently operating at the terminal gate, particularly the Boeing 777.

Another challenge occurs when the central PCA system transitions from the heating season to the cooling season or vice versa. During the shoulder seasons, there are days when actual temperatures create the need for either continued heating or cooling (i.e., the opposite need of that which the system has been configured for that month). This condition may occur multiple times during an operational day or for multiple days during the transition from one season to another. Whenever this type of condition exists, airlines rely on APU utilization to address the cooling or heating needs of the aircraft, as appropriate.

Finally, there are some hardstand positions (not connected to the terminal) that are used for regular passenger loading and unloading. These positions are not equipped with electric PCA or electric ground power, which results in aircraft using APUs or airlines using mobile, diesel-powered units for heating, cooling, and power. The airport and airline staff interviewed during the research considered the cost of installing electrical power at a hardstand to be prohibitively high. However, when considering these costs the financial model should take into account the longer life span associated with electrical infrastructure and wiring as opposed to the shorter useful life of mobile PCA and ground power equipment.

One airline is performing a study on current PCA and GPU utilization and the operational condition of each unit at Dallas–Fort Worth International. The airline intends to identify and address maintenance issues with regard to each PCA and GPU unit, including their capacity and



Figure 22. *Dallas-Fort Worth International Airport aerial view.*

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 3A, Warm/Humid Large hub, primary, commercial • Total passengers: 67,092,224 • Passenger growth: 2.30% • Cargo weight: 894,204.1 U.S. tons • Cargo growth: 7.80% • Number of passenger airlines serving: 28 <i>2017 data provided by the airport.</i>	• There are 165 operational gates. • There are 111 gates owned by the airport, all equipped with electric PCA and electric GPU. • There are 54 gates owned by airlines, all equipped with electric PCA and electric GPU. • PCA includes point-of-use and central systems. • 24 airport-owned, diesel, mobile GPU and/or PCA units are used for corporate aviation and when electric units fail. Additional mobile units are owned by airlines to service remote hardstands, which are not equipped with electric PCA or ground power. • Utilization rate is not systematically tracked, though newer gates are individually metered.
Major Tenants	Regulatory Issues
• Passenger airlines: American Airlines, Delta Air Lines, Spirit, and United Airlines • Cargo: Federal, United Postal Service, and DHL <i>Carriers with greatest market share listed.</i>	• VALE status: Eligible • Current NAAQS status: Moderate nonattainment for ozone • VALE participation: \$3,065,946 (FY 2016) for ground power at 23 gates and PCA for five gates; \$2,000,000 (FY 2014) for ground power and PCA at 12 gates

Figure 22A. *Dallas-Fort Worth International Airport specifications.*

reliability, as well as the condition of various components, such as air handlers, hoses, and power cables. The intention is to identify gates suitable for parking Boeing 787s.

Drivers for Installation

- To demonstrate industry leadership and to help meet environmental goals
- Air quality regulatory concerns and state and local regulatory considerations
- To satisfy customer service standards and expectations
- By request from airlines or tenants
- Availability of grant funding



Figure 23. Aircraft connected to electric PCA and 400 Hz ground power (left) and PCA hose and basket (right) (Source: Katherine Preston, Harris Miller Miller & Hanson, Inc.).

Finance Strategy

- Utilize FAA VALE grants.
- Leverage capital improvement program funds.
- Seek airline investment.

Planning and Policy

- Preventative maintenance program ensures maintenance is performed in advance to maintain system availability (i.e., functionality throughout the operating day).
- Dallas–Fort Worth International encourages airlines to use electric PCA and ground power at gates (Dallas–Fort Worth International Airport 2018).
- The airport charges airlines for electricity through terminal rents; not actual usage.

Tracking and Data Collection on Utilization

- Jet bridges are not individually metered, but newer gates are equipped with individual electric meters.
- To increase utilization, the airport is considering implementing a system to provide visual notification to pilots when their aircraft is connected to PCA. Lack of visual indicators that denote when aircraft are connected to the PCA can result in pilots continuing to run the APU. However, there are visual indicators when aircraft are connected to ground power.
- Informal observation-based utilization tracking has resulted in findings that indicate that—while utilization rates are high overall—there are a number of challenges.
 - Older equipment on some gates is unreliable, requiring frequent maintenance.
 - Equipment not right-sized for all aircraft results in aircraft using APUs. For example, PCA hoses and GPU power cables are not the correct length, or PCA units are not powerful enough for larger aircraft, particularly when ambient temperatures are very high.
 - Centralized PCA systems are programmed to switch from heating to cooling with seasonal changes rather than being readjusted daily, resulting in aircraft running APUs during shoulder seasons when the PCA temperature is either too warm or too cool to effectively condition the aircraft cabin based on ambient temperatures.
 - Ground crew misuse of equipment causes damage to component parts, which results in out-of-service equipment.
- Aircraft must use APUs or mobile, diesel-powered PCA and GPUs when parked at hardstands or maintenance facilities.

Lessons Learned and Best Practices

- Maintenance personnel are responsible for a variety of systems, including PCA, ground power, jet bridges, and baggage-handling systems. Often, when there are competing maintenance demands, jet bridges and baggage systems will receive priority, which results in longer outages for the PCA and ground power systems. Insufficient resources and/or prioritization of maintenance of these systems can result in extended critical system outages and aircraft utilizing APUs more frequently.
- In addition, maintenance personnel who also maintain IT systems place a higher priority on ensuring that critical ramp systems, such as ADP Safegate SafeDock, are available, particularly during periods of electrical storm activity.
- Newer aircraft, particularly Boeing 787s, require additional power due to advanced avionics. Such technology requires the replacement of existing serviceable, but undersized, gate electrification equipment to match system capabilities with the type of aircraft being serviced.
- The implementation of one-time digital combination locks on equipment allows the airport to keep track of individual ground crew members' use of gate electrification equipment; thus, providing accountability if damage occurs.
- Ribbed hoses are effective at preventing hose kinks, and insulated PCA hoses are more effective at keeping the air cool (or warm) as it is delivered to the aircraft.
- Hose reels and hose extension bins assist the ground crew in dispensing the proper length of PCA hose.
- Development of clear reporting responsibilities, as well as visually tagging items when equipment is out of service, is important for prompt response and elimination of redundant maintenance action requests.
- Consistent and adequate training of ground crew on proper operation and use of gate electrification equipment can be difficult because of high staff turnover.
- Companies that provide contracted ramp services to multiple airlines must comply with multiple standard operating procedures, which creates training challenges.

6.5 Denver International Airport (DEN), Denver, Colorado

Background

The Denver International Airport is a large hub airport, and—with its opening in 1995—one of the newest airports built in the U.S. (Figure 24). The airport currently has 116 gates with jet bridges, and six ground-load gates (Figure 24A). All are equipped with electric PCA and 400 Hz ground power, and it is standard operating procedure at Denver International to have gate electrification systems available at all gates. While utilization of these systems is not formally tracked, airport staff report that airlines consistently hook aircraft up to the equipment almost immediately upon arrival at the gates.

Thirty-nine new gates are planned to accommodate projected airport growth, and there is an active gate replacement program in place for older equipment. Power requirements are assessed for both new and replacement gates to meet the needs of newer aircraft, such as the Boeing 787. This assessment ensures adequate electrical load to heat, cool, and power larger aircraft and those with more advanced onboard avionics systems. Of the 39 new gates, four are planned to accommodate wide-body aircraft (e.g., Boeing 747s), and the remaining 35 are planned to accommodate narrow-body aircraft (e.g., Airbus 321s and Boeing 737s). The airport has a limited number of gates equipped with 28-volt power for smaller regional jets.

Equipment that was purchased with VALE grant funds are equipped with hour meters to track emissions reductions. These hour meters track the amount of time the equipment is in use but

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Figure 24. Denver International Airport terminals.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 5B, Cool/Dry Large hub, primary, commercial - Total passengers (2017): 61,379,396 - Passenger growth: 5.30% - Number of passenger airlines serving: 23 <i>Data from airport's 2017 Passenger Traffic Report</i>	- There are 116 gates with electric PCA and GPU, all owned by the airport. - There are six ground-load gates for narrow-body aircraft equipped with electric PCA and ground power. - There are 20 hardstands for remain-overnight positions served by airline-owned, mobile, diesel-powered PCA and GPUs. - A few remain-overnight positions have electricity available but no electric PCA or ground power provided. - Both centralized and point-of-use PCA systems are in place. - Individual PCA units are equipped with hour meters for tracking hours of use to estimate emissions reductions. - PCA and ground power systems are not equipped with individual electrical meters. However, all new and replacement gates will have electrical meters. - Utilization of gate electrification equipment as a function of actual use versus total possible use is not systematically tracked. Equipment at 39 future gates will be individually metered.
Major Tenants	Regulatory Issues
- Airlines with greatest market share: United Airlines, Southwest Airlines, and Frontier - Cargo carriers: World Port Cargo Support, DHL, FedEx, UPS, and United Airlines Cargo	- Current NAAQS status: Moderate nonattainment for ozone (8-hour), Maintenance zone for CO and PM10 - VALE participation: Total of \$1,889,674 in VALE grants awarded for PCA and GPU equipment in FY 2014 and 2018 (16 PCA units and 32 GPUs were funded with VALE grants).

Figure 24A. Denver International Airport specifications.

not electricity consumption. While the airport does track use of VALE-funded equipment and calculates estimated emissions savings from these data, the airport does not systematically track utilization of their gate electrification systems (i.e., the amount of time the equipment is in use compared to the amount of time the equipment could potentially be in use).

The airport has recently adopted new design standards that require all new and replacement gates to be equipped with individual electrical meters. A motivation for this change was to receive additional Leadership in Energy and Environmental Design, or LEED, credits for these future projects. The airport utilizes the Honeywell Enterprise Building Integrator platform as an energy management system. Currently, the platform is primarily used to monitor the HVAC system. But in the future, the airport plans to integrate other systems as additional submeters are installed.

Airport staff maintains the gate electrification systems. They use a system known as maintenance control for airlines to report any equipment outages or failures, enabling round-the-clock maintenance coverage of the system. Occasionally, third-party service providers are brought in for major issues, but in-house staff are normally equipped to repair any problems. Maintenance staff will coordinate with airport operations staff and the airlines. The airport also keeps backup ground power and PCA units in stock to install during systematic maintenance. Reliability is ensured via a preventative maintenance program, which is completed by a specialized team at night or during off-peak hours so that daytime operations are not disrupted.

The airport attributes the high (observed) utilization rate to universal equipage of gates, a reliable in-house maintenance and replacement program for jet bridges and gate electrification equipment, proper training and communications protocols, and airline policies.

Drivers for Installation

- Initial equipage was undertaken as a standard operating procedure to provide a service to the airlines and to demonstrate proactive environmental management and industry leadership and positive community.
- Bridge replacement is conducted based on changes in fleet composition (i.e., size and type of aircraft) and passenger volumes.
- Airlines are supportive of the airport's efforts to fund some of the equipment with VALE grants.

Finance Strategy

- Electric PCA and ground power systems were included in the initial construction of the airport, and the electrical system was designed for growth (i.e., the electrical system can handle the additional capacity of new gates and electric PCA and ground power).
- Subsequent equipment installation leveraged FAA VALE grants in 2014 and 2018.
- Electricity costs are built into airline rates and charges. Individual pieces of equipment are not metered and, therefore, it is not possible at this time to break out airlines' actual electrical use.

Operation, Maintenance, and Training

- The airport owns and maintains all the PCA and ground power equipment to ensure availability, reliability, and consistency.
 - Airport maintenance and electrical staff stock spare PCA and ground power units to keep equipment available when units need to be removed for repair or replacement.
 - Preventative maintenance on jet bridges and components is conducted by teams at night and during off hours to minimize time out of service.
 - Airport staff normally have capacity to repair units during the operational day.

- Maintenance budgets and staffing levels are sufficient to maintain equipment and to quickly repair damaged units. The airport has an active, well-planned jet bridge replacement program for equipment that has reached end-of-useful life (i.e., average three to four replacements per year).
- Airport staff will train one to two staff from each airline on the proper operation of gate electrification equipment or arrange for a manufacturer to provide training. The airlines are then responsible for training their own ground crews. This process results in a well-trained ground crew.

Planning and Policy

- Airport standard operating procedure is to supply PCA and ground power at all gates and ensure that the equipment is reliable and in good working order.
- No official language exists in airline leases that requires the use of PCA and GPU, but the airport noted that all carriers have their own policies concerning PCA and ground power use.
- Active jet bridge replacement program:
 - Equipment generally has a 20-year life span.
 - Station managers are involved in the phasing schedule for installing and replacing new units to ensure minimal downtime.
 - Airlines are involved with developing the replacement schedule. Early coordination is key to establishing proper timelines and planning gate use during construction periods.

Tracking and Data Collection on Utilization

- Utilization is not formally tracked, and equipment is not metered. However, new design standards require individual metering, and meters will come standard on 39 new gates.
- The airport uses a building energy management control system, primarily for managing HVAC systems. The airport plans to incorporate other systems over time but is not yet at the point of integrating PCA or ground power systems.
- Informally, airport staff have observed a high utilization rate, and airlines plug in immediately upon arrival at gates.

Lessons Learned and Best Practices

- Some PCA units are too large to serve the aircraft. If the aircraft only has one portal but the PCA unit has two ducts, connection may not be viable.
- Airports should consider new aircraft models coming online—such as the Boeing 737 series—to ensure that they can handle the electrical demand of large aircraft.
- Occasionally, equipment is damaged by ground crews pre-staging the power cables or PCA hoses in anticipation of an aircraft's arrival at a gate.

6.6 Kansas City International Airport (MCI), Kansas City, Missouri

Background

Kansas City International Airport is a medium hub airport located in a mixed climate zone (i.e., warm summers and cool winters) (Figures 25 and 25A). The airport currently consists of two separate terminals (B and C), while construction of a new, unified terminal is under way at the site of the previous Terminal A. When complete, the new terminal will replace the existing terminals. Currently, all gates at Kansas City International have jet bridges that are each



Figure 25. Aerial view of Kansas City International Airport terminals.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 4A, Mixed/Humid Medium hub, primary, commercial, reliever, military • Total passengers: 11,503,936 • Passenger growth: 4.19% • Cargo weight: 198,491,890 lbs. • Cargo growth: -2.63% • Number of airlines serving: 11 <i>2017 data provided by the airport.</i>	• There are 35 operational gates, which are owned by airport and leased on exclusive-use basis to airlines. • All gates are equipped with electric PCA and 400 Hz ground power; all are point of use. • A few gates have 28-volt power. • Airlines own mobile, diesel-powered PCA and GPUs to provide air and power to aircraft at remain-overnight parking positions or if PCA and ground power is out of service. • Gates and equipment are not individually metered, and utilization rates are not tracked. • Proactive maintenance practices ensure high reliability.
Major Tenants	Regulatory Issues
• Passenger airlines: Southwest Airlines, Delta Air Lines, American Airlines, and United Airlines • Cargo: FedEx and UPS <i>Passenger and cargo carriers with greatest market share listed</i>	• VALE status: Not eligible • Current NAAQS status: Attainment

Figure 25A. Kansas City International Airport specifications.

equipped with 30-ton ambient air PCA units (480V Jetaire) and 400 Hz ground power. The airport's proactive maintenance program ensures that jet bridges and gate electrification equipment are highly reliable with minimal downtime.

The airport owns and maintains—through the on-site, third-party contractor ABM—all of the jet bridges, including the gate electrification equipment (Figure 26). The airport and their maintenance contractor have found that preplanning for maintenance is critical to maintaining a high level of availability of gate electrification equipment, and they provide sufficient budgets to facilitate this. Because the terminals are not connected, and airlines have exclusive-use lease agreements for gates, gates are not interchangeable if a jet bridge is down. In the event gate

equipment is out of service, the airlines have to adjust operations as needed within their own gates. For this reason, it is crucial for maintenance to have sufficient staff, budget, and spare parts to maintain systems and complete repairs to quickly return to normal operations.

The airport has a CMMS that tracks all repairs, services, equipment, and components, including historical data for a 5-year time period. The CMMS also provides information about equipment age, which can be used to determine when and which components need to be replaced. Maintenance and technician history is held in the CMMS, and equipment audits can be obtained. To return equipment to service as soon as possible, the airport stocks spare PCA, ground power units, and key parts—such as preprogrammed motherboards—to repair or replace out-of-service equipment as quickly as possible. ABM monitors manufacturers' warranties of PCA and ground power spare parts to compare the cost effectiveness of using new versus reconditioned parts. Another maintenance best practice includes checking aircraft 400 Hz receptacle functionality and alerting the airline if a problem is found. Finally, a five-person overnight crew handles most significant jet bridge maintenance to ensure that these systems are available at the start of the next operational day.

The airport does not use hardstands for passenger loading, but there are many remain-overnight parking positions in use for airlines that pre-stage their aircraft for early morning flights. Airlines service remotely parked aircraft with mobile, diesel-powered PCA and GPUs, as remain-overnight positions are not equipped with electric PCA or ground power. The mobile units are also used if gate electrification equipment is out of service.

The airport stresses that frequent communication between parties is key to smooth operations. They hold a full maintenance crew weekly meeting to discuss all ongoing repairs and strategize priorities for the week ahead. Based on demand and needs, the meetings may include site-specific safety training, corporate safety training, or other trainings to enhance knowledge of the equipment. Often, the maintenance contractor will work with airline ground crew staff to provide training on equipment operations to reduce maintenance costs and ensure that systems run efficiently. All parties share the same goal of customer satisfaction, so they work to enhance communications between all parties and bring people together to achieve this goal. This effort has been effective in ensuring a well-trained ground crew.

Drivers for Installation

- Build stakeholder relations, and be a good neighbor.
- Demonstrate industry leadership and environmental proactivity.

Finance Strategy

- Gates were equipped with gate electrification equipment as part of a prior terminal renovation project.
- Jet bridges and gate electrification equipment is replaced as needed, and the oldest are currently approximately 16 years old.
- The jet bridge replacement program is included in the airport's capital program budget.
- The airport is not eligible for VALE funding.
- Gates are leased to airlines on an exclusive basis (airlines do not share gates). And electricity costs are built into lease terms (gates are not individually metered, but airlines are charged by square footage and number of jet bridges).

Planning and Policy

- An informal communications system between airport operations, maintenance staff, and the airlines is in place. Maintenance meets with airline station managers every few weeks to

discuss concerns or problems. If a problem arises, airlines call a duty phone, and a response is provided within 15 minutes.

- Airport maintenance communicates with pilots, encouraging PCA use instead of APUs even during hot weather.

Tracking and Data Collection on Utilization

- PCA and ground power equipment have hour meters that track time in use, but the meters are not tied into the airport's CMMS, and data must be retrieved manually.
- Anecdotal observations from airport and maintenance staff show that airlines nearly always plug into equipment when available unless they have a very quick turn time.
- Maintenance staff record run-time data during quarterly preventative maintenance checks but do not track utilization of the equipment in any other manner.
- Airlines track APU usage per aircraft but do not regularly maintain records of which gates a particular aircraft has used. Airline station managers generally track fuel use per day by APUs in aggregate.

Lessons Learned and Best Practices

- Maintenance staff keep critical system spare parts on hand to ensure a quick return to service.
- A five-person overnight maintenance crew ensures that heavy maintenance and preventative maintenance do not occur during the operational day, whenever possible.
- The airport employs a dedicated maintenance team to service all gate electrification systems to ensure consistency and reliability.



Figure 26. Clockwise from top left: 400 Hz ground power unit, aircraft connected to the PCA unit, 30-ton PCA unit, and aircraft connected to the 400 Hz ground power unit (Source: Jerome Cowart, ABM).

- Focus on training staff to prevent equipment misuse and to ensure that PCA and ground power units are shut down properly by ground crew, reiterating that it is crucial to use proper shut-down procedures and only use the emergency shut-down button in the event of a fire or a real emergency.
 - In general, the airport has observed that airline-employed, in-house ground crews are more reliable than contracted third-party ground crews.
- Safeguards employed for reducing equipment wear and tear include the following:
 - Pre-position hoses and cables.
 - Purchase power cable heads that are sturdy and designed to withstand being run over by aircraft once or twice without being damaged (cables currently supplied by JBM Aviation).
 - Use clips to prevent PCA hose from laying on the ground.
 - Utilize safety switches on jet bridges that prevent them from moving until the power cable is properly connected or stored.
- Airport maintenance staff report that the most common cause of ground power malfunction is damaged cable head pins, which prevent connection. There may also be damage on the aircraft receptor for ground power cable. Aircraft receptors can be tested with a hand-held gauge to determine if there is damage that would prevent a connection.

6.7 Memphis International Airport (MEM), Memphis, Tennessee

Background

Memphis International Airport is undergoing a concourse modernization project through 2021 to allow for consolidation of airline operations, retail, and general updates to the facility, which are all to be located in a redeveloped Concourse B (Figures 27 and 27A). Currently, airlines are operating out of gates in Concourses A and C. After the project is complete, all airlines will operate out of the 23 new gates in Concourse B, providing equivalent function, more flexibility in gate allocation, and no future incremental costs associated with equipping gates with gate electrification equipment, since this is a component of the modernization project.

Currently, maintenance of the gate electrification systems is handled by a mix of airport staff, airline staff, and third-party service providers. Airport-owned gate equipment is maintained by staff. Airlines generally provide operations and maintenance on their own gate equipment using airline staff and third-party support. Some critical parts, including compressors, are available on site, but there is not a large inventory of spare parts maintained on site. Parts are ordered and shipped as needed, which can cause delays in repairing systems.

Maintenance communications include regular meetings between the airport and airlines to systematically discuss issues. Training is provided for ground service handlers, but due to high turnover training is not as effective in molding behavior. Communication between airport and airlines is key to efficiently report, respond to, and resolve equipment outages. Airport staff collaborates with airline station managers and ramp staff. Regular maintenance staff are not available after hours or on weekends, which can present a challenge to utilization if repairs are needed during these times. Outside of normal working hours, the airlines contact airport dispatch to radio after-hours staff.

One major challenge for Memphis International is ensuring that the electric PCA is utilized during hot weather periods over the summer months. To combat the heat, the airport has upsized all PCA units from 30 tons to 50 tons. If it is too hot onboard the aircraft, some pilots will keep APUs running. The airport does not collect information from airlines with regard to



Figure 27. Aerial view of Memphis International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 3A, Warm/Humid Large hub, primary, commercial, military - Passengers: 4,196,259 - Passenger growth: 4.88% - Cargo weight: 9,562,537,748 lbs. - Cargo growth: 0.34% 2017 data provided by the airport.	- There are 26 operational gates. Terminal B is currently closed for construction. 11 gates equipped with electric PCA, owned by the airport 11 gates equipped with electric GPU, owned by the airport - All PCA units are portable, and three mobile units are diesel powered. No central units are in service. - VALE-funded units are tracked by hour meters to calculate emissions reductions. - No electrical meters are on equipment, and systemwide utilization rates are not tracked.
Major Tenants	Regulatory Issues
- Passenger airlines: American Airlines, Allegiant Air, Delta Air Lines, Frontier, Southwest Airlines, and United Airlines - Cargo: FedEx and UPS	- VALE status: Eligible - Current NAAQS status: Maintenance zone for CO and ozone (8-hour) nonattainment areas (lead nonattainment or maintenance not confirmed) - VALE participation: \$2,446,731 for 11 GPUs and 11 PCA for 11 gates (FY 2016)

Figure 27A. Memphis International Airport specifications.

APU use, and protocols vary by airline. One airline has a best practice to turn off the APU at every turnaround.

Another challenge is related to how hoses are stored and used. The effectiveness of hoses are decreased when ground handlers do not remove kinks. Airport staff have observed that hose equipment needs may also vary by plane size. Longer hoses are needed for larger planes but, in other cases, the length is not necessary. To address this challenge, one airline has implemented a rack system to keep hoses off the ground, minimize wear, and provide predictable hose length. Another option is retractable hose equipment that enables the hose to stay off the pavement and prevent heat transfer. The convenience of rack systems and retractable hose use will still vary based on aircraft type.

Drivers for Installation

- Ongoing modernization project will move all gates to Concourse B, where they will all be equipped with gate electrification systems.
- Both airport and airlines consider installation of gate electrification systems a sound business decision, enabling them to meet shared business goals.
- No state or local regulatory pressure currently exists.

Finance Strategy

- New gates will be included as a component of the Memphis International Airport Modernization project.
- The airport plans to apply for another VALE grant to support additional gates.

Planning and Policy

- No formal airport policy exists that requires airline use of electric PCA and ground power.
- Airlines train their own ramp staff annually on equipment use.
- Airlines have preventative maintenance programs to maintain equipment in a standardized manner.

Tracking and Data Collection on Utilization

- Equipment purchased with VALE grants is equipped with hour meters to track use for estimating emissions reductions. However, the airport does not formally track PCA and ground power utilization as a percentage of time the equipment is in use when available.
- Gates are only metered with hour meters; not with electrical meters. Therefore, electricity use of the equipment is not tracked on a gate-by-gate basis.
- The airport must log hours of run time for the VALE-funded units, as per grant requirements.
- Airlines use some hardstand operations while the airport is undergoing construction. Hardstands are serviced by mobile, diesel-powered PCA and GPUs, or aircraft run the APUs.

Lessons Learned and Best Practices

- Three airlines provided written assurances in the airport's VALE grant application that they intend to use the VALE-funded electric PCA and ground power equipment.
- Maintaining aging equipment and availability of spare parts presents maintenance issues, causing delays in bringing equipment back in service.
- Communication with equipment manufacturers with regard to maintenance needs and pre-planning is important.
- Airport and airlines identified a need for additional training for equipment users on the proper operation of the equipment to prevent damage.

6.8 Phoenix Sky Harbor International Airport (PHX), Phoenix, Arizona

Background

The City of Phoenix owns and operates Phoenix Sky Harbor International Airport (Figure 28). Due to the extremely hot and dry climate, electric PCA and 400 Hz ground power have historically been important components of the airport's infrastructure to support operations



Figure 28. Phoenix Sky Harbor International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 2B, Hot/Dry Large hub, primary, commercial - Passengers: 43,921,670 - Passenger growth: 1.20% - Cargo weight: 375,260 tons - Cargo growth: 5.70% - Number of airlines serving: 16 <i>2017 data provided by the airport.</i>	- There are 97 operational gates, with a mix of owned by the city (airport) and owned by airline. - All 97 gates equipped with 400 Hz ground power. - All 37 city-owned gates are equipped with electric PCA. Most, but not all, airline-owned gates have electric PCA. - Combination of central system and point of use - One central system is owned by the airport, which serves six gates. And three central systems are owned by American Airlines. - Four regional jet hardstands - Electric ground power at multiple FedEx cargo stands - Utilization rate not systematically tracked
Major Tenants	Regulatory Issues
- Passenger airlines: American Airlines, Southwest Airlines, Delta Air Lines, and United Airlines - Cargo: UPS, FedEx, Air Transport International, and DHS–Atlas Air <i>Passenger and cargo carriers with greatest market share listed</i>	- VALE status: Eligible - Current NAAQS status: Maintenance zone for CO, Moderate for ozone (8-hour), and Serious for PM10. - VALE participation: Grant received in FY 2015 for electric ground support equipment charging stations but not for gate electrification equipment

Figure 28A. Phoenix Sky Harbor International Airport specifications.

and to ensure customer safety and comfort. The gates are a mix of city owned (airport) and airline owned (Figure 28A). All 97 gates have 400 Hz ground power, all 37 city-owned gates are equipped with electric PCA, and the majority of the 60 airline-owned gates have electric PCA.

The PCA systems are designed and sized appropriately to handle the extreme Arizona heat and can effectively cool aircraft cabins to comfortable conditions even when ambient temperatures are up to 120°F. The jet bridges have two air-handling units: one to cool the aircraft and one to cool the jet bridge. Otherwise, jet bridges will have a separate air-conditioning unit on the roof. Conditioning the jet bridges helps to keep passengers comfortable during the loading and unloading process and prevents the jet bridge from drawing cool air from the aircraft cabin when the door is open.

Maintenance responsibilities are shared by the airport and airlines. Some airlines have internal maintenance staff and others have contracted staff. Airport maintenance staff maintain a small inventory of spare parts and three portable units for both PCA and ground power in case

gate equipment is down for an extended period or if there are emergency landings. When maintenance issues arise with the central plant systems, the repair of these systems takes priority since they serve multiple gates. The airport has a maintenance plan, which includes replacing equipment 2 to 3 years ahead of standard expected useful life, depending on reliability of equipment. This plan helps to maximize system availability.

Drivers for Installation

- Equipment was originally installed in the late 1990s to address airlines' needs, passenger comfort, and air quality issues.
- International concourse central PCA system was installed, since aircraft APUs do not suffice during the hottest months.

Finance Strategy

- Airline paid for acquisition and installation of equipment on their gates through capital programs budget (no VALE grant funding).
- Airlines funded the development of central plant and for equipment on the gates they own.
- Airlines are charged for electricity use based on their gate lease terms.

Planning and Policy

- The airport facilitates coordination and collaboration with airlines concerning airline and airport facility needs.
- There are no requirements or guidelines from the airport to airlines that dictate use of gate electrification equipment.

Tracking and Data Collection on Utilization

- Utilization of electric PCA and 400 Hz ground power is not tracked.
- The centralized plant on the international concourse has an electrical meter.
- The city is not permitted to charge airlines directly for electricity, so fees are included in rates and charges.

Lessons Learned and Best Practices

- Although the airport does not formally track utilization, airport staff note that utilization rates are high as airlines want to save fuel and keep passengers comfortable (weather can get too hot in Phoenix for APUs to effectively cool aircraft cabins).
- Preventative maintenance plan—The airport has 5- and 10-year maintenance plans:
 - For standard expected useful life of equipment, the airport aims to be ahead of standard by 2 to 3 years, depending on reliability (i.e., not waiting until equipment is at the very end of useful life to replace).
- Situations that result in airlines using APUs (anecdotal observation from airport staff) include:
 - Quick turnarounds;
 - Operator error, particularly with regard to the order of connecting power cables to aircraft where two are needed;
 - Operator error in system start-up and shut down; and
 - Older aircraft can sometimes trip the ground power equipment.
- Established procedural systems to track and manage maintenance of electric PCA and ground power equipment help minimize time out of service.

6.9 Pittsburgh International Airport (PIT), Pittsburgh, Pennsylvania

Background

The existing terminal building at Pittsburgh International Airport opened in 1992 (Figure 29). It is equipped with electric PCA and 400 Hz ground power on 68 jet bridges (Figure 29A). The decision was driven in large part by US Airways' desire for gate electrification due to the airline's presence as the dominant carrier at Pittsburgh International during that time.



Figure 29. Pittsburgh International Airport aerial view.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 5A, Cool/Humid Medium hub, small, primary, commercial, reliever, military - Passengers: 8,988,016 - Passenger growth: 8.2% - Operations growth: 5% - Cargo weight: 148,342,856 (lbs.) - Cargo growth: -1.30% - Number of airlines serving: 14 <i>2017 data provided by the airport.</i>	- There are 76 operational gates, 68 with jet bridges. - All 68 jet bridges are equipped with electric PCA and 400 Hz ground power. - Six exclusive-use gates are equipped with electric 28 VDC ground power, acquired by the airline and installed and maintained by the airport. - PCA is provided by a central system along with auxiliary heater units. - All gates are airport owned and leased to airlines on both an exclusive-use and common-use basis. - Airlines use mobile PCA and GPUs to service aircraft at gates without electric PCA or 400 Hz ground power.
Major Tenants	Regulatory Issues
- Passenger airlines: Southwest Airlines, American Airlines, Delta Air Lines, United Airlines, JetBlue Airlines, and Allegiant - Cargo: FedEx, UPS, and Qatar Airways Cargo <i>Passenger and cargo carriers listed by greatest market share</i>	- VALE status: Eligible but has not participated - Current NAAQS status: Maintenance zone for CO and PM2.5 and Marginal ozone (8-hour)

Figure 29A. Pittsburgh International Airport specifications.

The airport recently announced plans to modernize the terminal, updating how the airport looks and operates. The modernization project includes updates to both the gates and jet bridges. The airport owns and maintains the electric PCA and ground power systems, leasing gates to airlines on either an exclusive-use or a common-use basis. In light of the impending upgrades, airport staff are tasked with maintaining the functionality of existing systems and equipment until the modernization plan is complete.

The airport has a unique central air-chilling system for the PCA, which is designed to provide comfortable conditions in any season. This central plant opened in 1992, along with the terminal building. The system as a whole is now 25 years old (though individual components have been replaced), and maintenance presents an ongoing challenge. The central chiller system provides air to the PCA units and has a unique design in which water is used for cooling in conjunction with electricity; there are no outside cooling towers. There are two separate systems that allow for summer cooling and winter heating with the assistance of auxiliary heater units. Therefore, determining the system switch-over date presents a challenge. The PCA temperature can be adjusted somewhat, depending on weather conditions, but this often presents challenges during months when daily temperatures fluctuate (fall and spring).

Operational costs for electric PCA and ground power are paid by the carriers through direct charges or as built-into leases. Airlines with exclusive-use gates are charged for electricity consumption per gate (tracked through electrical meters at the gates). These data are gathered automatically and billed to the airlines each month. Tenants at common-use gates are billed a set fee, which includes electricity costs but is not based on actual usage. This arrangement is referred to as a “per-turn fee” for common use gates.

The airport maintains all gate electrification equipment and upholds a high level of system availability, despite the challenge of aging equipment. The airport has a number of best practices in place to maximize system availability. These include dedicated maintenance personnel for the jet bridges and gate electrification equipment; 24-hour coverage of maintenance staff; and regular communications about operational status of equipment between airport operations staff, maintenance staff, and airline staff. When problems arise, the airport works with the airlines to identify and resolve the problem. For example, in winter 2017–2018, the air temperature from the PCA equipment at one gate was too warm, prompting pilots using that gate to routinely disconnect from the PCA and utilize APUs to maintain a comfortable cabin temperature. Airport maintenance staff investigated the source of the problem and determined it to be caused by a faulty valve, which was consequently fixed.

Drivers for Installation

- Acquisition and installation of the original equipment was driven by airline interest. At the time, Pittsburgh International was a hub for US Airways.
- The airport did not identify any regulatory drivers for the installation of gate electrification equipment.
- The airport has a number of environmental initiatives and goals, but there has not been any specific community pressure concerning air quality.

Finance Strategy

- Installation was initially financed in 1992 as part of the capital project for the existing terminal.
- Upgrades to the gates and jet bridges are planned for the current modernization project and will be financed as part of that capital project.
- The airport has not utilized VALE funding in the past, but it may consider it in the future.

Planning and Policy

- Original installation was driven by US Airways, but all airlines are supportive. The airport is working in collaboration with airlines on system and equipment needs for the modernization project.
- The airport routinely reviews a 3-year maintenance history to gauge system needs and to appropriately plan for system operations and maintenance budget.
- Repair costs are absorbed by the airport, but there are mechanisms in place for charging carriers and operators if damage to equipment occurs from negligence or extreme circumstances.
- The airport's vice president of Terminal Operations works with air carriers concerning large or recurring issues to collaborate on solutions.

Tracking and Data Collection on Utilization

- The airport does not track PCA and ground power utilization, but anecdotal observations provide evidence that utilization rates are very high where equipment is available and operable.
- Electricity consumption is tracked at gates with individual meters, and airlines are consequently billed for their use.
- The airport tracks complaints concerning when equipment is out of service or in need of maintenance.

Lessons Learned and Best Practices

- Airport staff observe that the following conditions result in aircraft using APUs:
 - Ground crew misuse of equipment,
 - PCA hose kinks and damaged power cable heads and pins,
 - High ambient temperatures render PCA ineffective (though the air temperature of PCA can be adjusted),
 - Other weather hazards prevent ground crew from connecting aircraft, and
 - Worn PCA valves prevent PCA system from effectively conditioning aircraft.
- Maintenance best practices include:
 - Constant real-time communication between airport operations, maintenance staff, and airline staff in the event of equipment outage to enable quick repairs and notification when equipment is back in service;
 - Employ round-the-clock maintenance staff, including electricians, and a dedicated jet bridge maintenance crew to minimize repair time due to staff expertise;
 - Maintain comprehensive maintenance records to enable staff to identify issues that result from misuse of the gate electrification equipment in comparison to equipment failure (e.g., due to age);
 - Maintain an on-site spare parts inventory to decrease maintenance delays as a result of ordering equipment from off-site manufacturers; and
 - Preserve additional gate capacity to provide some flexibility if a jet bridge goes out of service.

6.10 Portland International Airport (PDX), Portland, Oregon

Background

Portland International Airport (Figure 30) is focused on enhancing the quality of life for the communities it serves and, as stated in the Port of Portland *Environmental Report 2016/17* (2017), “integrat[ing] environmental stewardship into our daily operations.” Portland International has



Figure 30. Portland International Airport aerial view.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 4C Mixed/Marine Large hub, primary, commercial • Passengers: 19,080,494 • Passenger growth: 4.0% • Cargo weight: 246,917 tons • Cargo growth: 6.8% • Number of airlines serving: 16 <i>2017 data provided by the airport.</i>	• There are 53 operational gates: 42 gates have jet bridges, and 12 have hardstand gates. • 41 of the passenger boarding bridges are equipped with electric PCA (31 are airport owned, and nine are airline owned), all point of use. • 45 gates are equipped with electric GPUs that are owned by the airport. • Hardstands and unequipped passenger boarding bridge gates are served by airline-owned, mobile, diesel-powered PCA and ground power units. • VALE-funded equipment use is tracked to estimate emissions reductions, but utilization rates are not systematically tracked.
Major Tenants	Regulatory Issues
• Passenger airlines: Alaska, Southwest Airlines, United Airlines, Delta Air Lines, Horizon Air, and American Airlines • Cargo: FedEx and UPS <i>Passenger and cargo carriers with greatest market share listed</i>	• VALE status: Eligible • NAAQS status: Formerly maintenance area for CO. In attainment for all. • VALE participation: FY 2016: \$5,700,600 for 26 PCA units for 26 gates

Figure 30A. Portland International Airport specifications.

a number of environmental goals, including minimizing the impact of operations on air quality. In addition, Portland International community stakeholders are active, engaged on environmental initiatives, and broadly concerned with air toxics in their local environments. The installation of electric PCA and 400 Hz ground power units contributes to meeting the airport's air quality and greenhouse gas emissions reduction goals.

In 2016, the airport was awarded a \$5.7 million VALE grant from FAA, enabling the purchase and installation of 26 electric PCA units (Figure 30A). Use of the newly installed equipment—in combination with electric GPU use—is expected to result in substantial emissions reductions at the airport. Over 13 years, Portland International estimates that the units will “reduce fuel

consumption by approximately 6 million gallons, carbon monoxide emissions by 122 tons, and carbon dioxide by 62,000 tons” (Port of Portland 2017). The remaining 15 passenger boarding bridges have electric PCA and 400 Hz ground power units that were purchased and installed by the airport.

To maintain VALE grant compliance, the airport tracks hours of use, as well as energy use data for the VALE-funded PCA units. This information is collected quarterly. The airport plans to install hour meters on the remaining PCA units (i.e., those that were not funded with VALE grants) in the future to account for energy use and factor it into their greenhouse gas inventories. The airport also foresees investing in upgrades to the remaining passenger boarding bridges in the future, with a plan to invest in units that have electric PCA, 400 Hz ground power, and individual metering as standard components.

The ownership structure of the gates is mixed. The airport owns 31 of the passenger boarding bridge gates, and airlines own nine. The gates are leased to the airlines, with some common use and others exclusive use. The maintenance of the electric PCA and ground power units are handled by in-house airport maintenance staff and managed through a maintenance operations center. The ground handling crew for airlines includes both airline staff and contracted employees. Maintenance requests or issues are handled through informal communication between airport staff and carrier staff. PCA units receive quarterly maintenance while GPUs receive both quarterly and annual comprehensive preventative maintenance procedures. In addition, Portland International maintains round-the-clock maintenance coverage for the 400 Hz ground power units. Finally, airport maintenance staff have a spare parts inventory to facilitate quick repairs as needed, though the Port’s ability to maintain a comprehensive spare parts inventory is a challenge because of lack of equipment standardization.

Drivers for Installation

- Air quality regulatory considerations are currently in attainment for CO but were previously in maintenance.
- VALE grant and airline support are available.
- Airlines have historically pursued installation of electric PCA and ground power, in part, due to lower fuel costs and, in part, motivated by decreased maintenance costs associated with APU use.
- The Port of Portland has a 14001-certified Environmental Management System under which objectives and targets are established, including a target to assist airlines in meeting their industry environmental and carbon reduction goals. Electric PCA greatly reduces aircraft greenhouse gases, criteria pollutants, and air toxics, as well as reduces fuel consumption.

Finance Strategy

- Capital comes from airport, airlines, and external funding.
- The FAA VALE grant was leveraged for funding 26 point-of-use systems in 2016.

Planning and Policy

- Stakeholders involved in the planning and acquisition of electric PCA include many airport departments, such as finance, operations, maintenance, and engineering.
- The jet bridge replacement plan includes investment in bridges that have electric PCA and 400 Hz ground power, as well as individual meters as standard components on the new equipment.

- An Operational and Maintenance Plan is in place.
- Preventative maintenance includes quarterly maintenance and annual maintenance of the units.
- Airline policies improve utilization.

Tracking and Data Collection on Utilization

- The airport tracks hours of use and energy use information for equipment purchased with VALE grants as part of grant compliance.
- The airport does not track utilization of units not funded with VALE grants, though it plans to do so in the future.
- Due to the cost and complexity associated with metering, Portland International plans to utilize a single meter on future jet bridges to save costs associated with additional submetering of components.

Lessons Learned and Best Practices

- Standardization of PCA and ground power equipment and units is key for decreasing maintenance labor and cost. This results in:
 - Reduced training complexity and
 - Spare part compatibility.
- Retrofitting jet bridges leads to greater complexity and cost than purchasing jet bridges already outfitted with PCA, GPU, and metering.
- The airport would like to have equipment capable of automatically uploading information from PCA and ground power into its CMMS.
- Anecdotal observations by airport staff identify the following reasons for non-use of electric PCA and/or ground power:
 - Operator error in connecting the power cable or PCA hose kinks;
 - Operator failure to properly turn on equipment; and
 - Operator damage to power cable pins, power cables, or PCA hoses (i.e., not stored properly or being run over by ground service equipment vehicles).
- Insufficient training for ground crew inhibits utilization, which may be affected by high turnover of ground crew.

6.11 Sacramento International Airport (SMF), Sacramento, California

Background

Sacramento International Airport was one of the first airports in the U.S. with 100 percent of jet bridges equipped with electric PCA and 400 Hz ground power units (Figure 31). The airport is located in a valley with poor air quality, providing a strong incentive for measures to reduce air pollutant emissions.

Sacramento County and the other surrounding counties do not meet EPA NAAQS for 8-hour ozone or PM 2.5. The airport owns and maintains all of the equipment and funded the acquisition, installation, operation, and maintenance of all PCA and ground power equipment (Figure 31A). It has a rigorous maintenance program that results in very minimal down time, which has resulted in a high system utilization rate (i.e., >95%, exclusive of regional jets), according to a study conducted in 2011 (B. Taylor, personal communication, Nov. 18, 2011). The biggest challenge to the use of these systems (or conversely, a reduction in the use of APUs at the gates) is related to weather. When ambient temperatures are above 100°F, the PCA



Figure 31. Sacramento International Airport aerial.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 3B, Warm/Dry Medium hub, primary, commercial • Passengers: 10,912,080 • Passenger growth: 7.8% • Cargo weight: 148,885,057 lbs. • Cargo growth: 7.2% • Number of airlines serving: 17 <i>2017 data provided by the airport.</i>	• The airport has 31 operational gates, all equipped with electric PCA and ground power. • Seven gates have both 400 Hz and 28 VDC. • Three gates have two 400 Hz ground power units to accommodate wide-body aircraft. • All gates are owned and maintained by the airport. • Diesel-powered mobile units are used for hardstand operations. • Utilization rate is not systematically tracked, but a limited study was completed in 2011 that showed high utilization (>95%) of gate electrification equipment.
Major Tenants	Regulatory Issues
• Passenger airlines: AeroMexico, Alaska, American Airlines, Delta Air Lines, Horizon, JetBlue Airlines, Southwest Airlines, Skywest/Compass, and United Airlines • Cargo: FedEx and U.S. Postal Service Express Mail	• VALE status: Eligible, though VALE grants are not used. • Current NAAQS status: Moderate zone for PM2.5 and Severe zone for ozone (8-hour)

Figure 31A. Sacramento International Airport specifications.

equipment has difficulty cooling the aircraft, and pilots tend to leave APUs running. Although both the airport and airlines feel that the equipment is right-sized, there may be opportunities to address the heat-related challenges with some component modifications that keep PCA hoses off the hot pavement, for example.

Drivers for Installation

- Poor regional air quality was the primary motivation for the airport to install gate electrification equipment.

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- The secondary motivation was to provide attractive service to air carriers due to understood fuel and maintenance cost of running the APU.
- An unforeseen co-benefit has been reduced congestion of the ramp area, resulting in more efficient and safer ground operations.

Finance Strategy

- Equipment installed on the original Terminal B jet bridges was funded with the operating budget.
- All Terminal A and new Terminal B equipment was funded with the Capital project budget. Terminal A opened in 1998, and the new Terminal B opened in 2011.
- The airport leadership was committed to installing PCA and ground power equipment at each gate because of regional air quality concerns.
 - The airport is eligible for VALE grants but has not utilized federal grants for the acquisition or installation of the equipment.
 - Airlines are not charged directly for electricity; it is included in rates and charges.
- Airlines have their own internal cost calculations and have found that there is a benefit to using PCA and ground power instead of APUs.

Operation, Maintenance, and Training

- Airport staff maintains the equipment, and jet bridges (including PCA systems) are given priority, especially during summer months.
- Both corrective and preventative maintenance are performed on system components to minimize down time.
- Some airlines have in-house ground crews and conduct their own training on gate electrification equipment use. Other airlines use a third-party ground handling company, primarily GAT Airline Ground Support, Inc.

Planning and Policy

- Monthly station managers meetings are conducted so that airport staff and airlines can coordinate on issues, including those related to gate electrification equipment.
- Airport maintenance staff regularly communicate with airline and ground crews on the status of equipment when there is a maintenance issue.
- There is no airport requirement for airlines to use equipment, but all airlines reported having corporate policies to this effect.
 - Other related policies include airlines requesting passengers to lower window shades or precooling aircraft before arriving at gate.

Tracking and Data Collection on Utilization

- Airport conducted a survey of PCA and 400 Hz ground power use by airlines in 2011. This involved staff observing airline operations over 24 hours.
- The airport found a utilization rate of ground crew connecting aircraft to gate electrification equipment of greater than 95 percent (less than 5 percent of the time the aircraft were not connected to equipment).
- One airline representative reported monitoring daily APU fuel burn via a dashboard to reduce costs.
- Both the airport and airlines reported the most significant challenge to utilization of PCA is hot weather. PCA equipment cannot effectively cool aircraft when temperatures get extremely hot.

Lessons Learned and Best Practices

- When ambient temperatures are above 100°F to 105°F, the PCA has difficulty cooling aircraft.
- Pavement heat transfers to hoses, even with insulation. PCA air temperature increases over 30°F to 40°F from the time it leaves the PCA unit to the time it gets to aircraft. The airline sees the problem but cannot alter equipment—such as attach the PCA hose to the bridge—because it is owned by the airport.
- Short turns of 24 minutes or less are not possible to cool down the cabin with PCA.
- Terminal A gates are submetered. However, these data are not tracked or used. Terminal B gate meters include all electricity use and cannot break out PCA and ground power use.
- Data are currently not available for calculating the cost benefit of highly utilized gate equipment.
- 28 volt cables are not being used because the cables are not long enough to reach where the aircraft (i.e., DH8s) park.
- Several factors seem to influence the high utilization rate at Sacramento International:
 - Universal equipment availability,
 - Reliable and prompt maintenance (and the airport's reputation with air carriers for having available, working equipment),
 - Good two-way communication between airport staff and airlines on the status of equipment through daily communication and weekly station manager meetings,
 - Airport ownership and control of all equipment,
 - Right-sized equipment for fleet, and
 - Strong motivation with regards to poor regional air quality.

6.12 San Diego International Airport (SAN), San Diego, California

Background

The San Diego International Airport, owned and operated by the San Diego County Regional Airport Authority, is a large hub airport located in Southern California, which has both current and historical air quality challenges (Figure 32). Because of these challenges, the airport has aggressive air quality and environmental goals and has voluntarily developed an air quality management plan and entered into a memorandum of understanding (MOU) with the Attorney General for the State of California in 2008 for the reduction of greenhouse gases. One measure specifically listed in both the MOU and the air quality management plan is the installation of electric PCA and 400 Hz ground power on all new or refurbished gates. Now, all gates are equipped with both electric PCA and 400 Hz ground power (Figure 32A).

The airport has installed the equipment in multiple phases and, as a result, not all of the equipment is the same on each gate. The reliability of the equipment is high and is well maintained by the third-party contractor (Siemens), but the inconsistency in equipment and meter type makes data collection challenging. The equipment-use information must be collected manually and does not automatically upload into the airport's automated information management and monitoring system (AIMMS).

The airport tracks use of PCA and ground power equipment, as required by VALE (hours of use), and has undertaken informal observational studies, which demonstrate anecdotally that utilization is high and aircraft are plugging in quickly upon arrival at the gate. As the maintenance provider, Siemens also tracks usage of equipment but does not systematically report it or provide the data to the airport unless asked. The airport has attempted to track utilization of gate electrification equipment in a more detailed, systematic manner, but it does not currently have a



Figure 32. Aerial view of San Diego International Airport (Source: San Diego International Airport).

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 3B, Warm/Dry Large hub, primary, commercial - Passengers: 22,173,493 - Passenger growth: 7.00% - Cargo weight: 166,135.2 (tons) - Cargo growth: -1.30% - Number of airlines serving: 17 <i>2017 data provided by the airport.</i>	- There are 51 operational gates, with 40 owned by the airport and 11 owned by the airline (mixed ownership structure). - All gates are equipped with electric PCA and 400 Hz ground power and all point-of-use systems. - Hardstands are used for overnight parking only. 56 diesel-powered mobile PCA and GPU units service the aircraft when gate electrification equipment is out, at hardstands, or for business aviation jets (airline and fixed-base operator owned). - Utilization rate is tracked through hour meters and through electric meters on some gates.
Major Tenants	Regulatory Issues
- Passenger airlines: American Airlines, Alaska, Delta Air Lines, Southwest Airlines, and United Airlines - Cargo: DHL Express, FedEx, and UPS <i>Passenger and cargo carriers with greatest market share listed</i>	- VALE status: Eligible - Air quality status: Federal nonattainment (moderate) for ozone 8-hour and state nonattainment for ozone 8-hour, ozone 1-hour, PM 2.5, and PM 10 - VALE participation: FY 2013 grant for PCA at 18 existing gates, FY 2011 grant for PCA at 10 existing gates, and PCA and ground power at 10 new gates as part of terminal expansion project

Figure 32A. San Diego International Airport specifications.

satisfactory method of obtaining airline daily schedule information or APU-use information. The airport is exploring using gate utilization software programs to obtain more granular insights into the types of aircraft using each gate and the duration at each gate.

Drivers for Installation

- The airport's MOU with the California Attorney General is designed to reduce greenhouse gases.
- Airlines support fuel savings, efficiency, and safety.
- Availability of grants was less of a driver but helpful.

Finance Strategy

- Southwest Airlines purchased their own PCA and ground power equipment for their 11 gates.
- The airport funded the electrification of their 40 airport-owned gates through the capital projects budget as part of the modernization project and received VALE grants for the remaining gates in FY 2011 and FY 2013.

Planning and Policy

- Some airlines report that plugging into PCA and ground power is one of the first items on their operations checklist (Figure 33).
- While use of PCA and 400 Hz ground power is not required by the airport, the MOU language is included in the lease agreements to encourage use.
- The airport conducted early coordination with airlines during the VALE application process to ensure their support.

Tracking and Data Collection on Utilization

- Electricity is included in airlines' rates and charges. Airlines are not charged directly based on electricity use, even though some jet bridges are individually metered.
- Some individual jet bridges are metered. However, since the gate electrification equipment was purchased in two phases, the equipment and meters are not consistent. The information from the meters can be challenging to gather and, historically, has not integrated automatically into the AIMMS. But the San Diego County Regional Airport Authority has initiated a project to better incorporate jet bridge data into AIMMS.
- The airport has conducted informal utilization observations and reports high rates of utilization with quick connection times. However, the observational study did not evaluate whether aircraft APUs were still running.

Lessons Learned and Best Practices

- The airport is currently integrating all metering data into the AIMMS.
- The airport is in the process of procuring gate utilization software to get more granular insight into types of aircraft and duration at gates. It expects the software to be fully operational in 2019.



Figure 33. PCA and GPU connection at SAN jet bridge (Source: San Diego International Airport).

6.13 Seattle–Tacoma International Airport (SEA), Seattle, Washington

Background

The Seattle–Tacoma International Airport (Figure 34) is one of the fastest-growing airports in the U.S., with more than 43 percent growth in passenger traffic since 2012 (Nordstrom 2018). As such, the airport is undergoing expansion and construction. All gates with jet bridges have electric PCA and 400 Hz ground power; the exact number varies depending on construction, but there are currently approximately 70 jet bridges (Figure 34A). The gates and PCA units started operation in a phased approach in 2013. The airport also has a hardstand terminal that serves six gates, which are not equipped with electric PCA or 400 Hz ground power.

The airport has a unique centralized PCA system that was designed to accommodate 72 gates, with the capacity to accommodate up to 90 gates (Figure 35). The PCA system has a central chilled water plant and five central hot water plants (Figure 36). Seattle–Tacoma considers the PCA system as HVAC equipment and has integrated them into the airport’s building automation system. The airport worked with the PCA equipment supplier through the procurement process to install Siemens’ compact controllers in each PCA unit. The controllers are compatible with the airport’s building automation system, which enables direct communication between the PCA and the building automation system. The airport built graphics, information, and a programming interface into the building automation system to control the PCA systems. The building automation system allows the airport to monitor a variety of the PCA’s dimensions, including:

- Notification when the Auto-lock/Auto-level is engaged on a jet bridge, indicating that an aircraft has arrived;
- Whether the PCA fan blower is turned on;
- The size of the aircraft based on the position of the variable frequency drive selector switch, which controls the speed of the fan to accommodate smaller and larger aircraft, as necessary;
- Outside ambient temperature and temperature gauges to measure aircraft cabin temperature, which helps the airport determine what temperature the air in the PCA systems should be;
- Temperature of air leaving the PCA through a PCA outlet temperature gauge to determine whether the cooling and heating settings are sufficient or to possibly indicate if there is a problem with the PCA hose; and
- The chilled water valve and the hot water valve.

The system does not provide information on whether the APU is running, since the APU is not connected to the system. In some cases, pilots will leave APUs running even when aircraft are connected to the PCA. It is not always known why, but some pilots have claimed that leaving APUs running when aircraft are connected to the PCA is to better circulate air on hot days. In addition to monitoring the variables listed above, Seattle–Tacoma tracks hours of PCA use, as per VALE grant requirements.

Maintenance on the PCA and 400 Hz ground power systems is handled through Seattle–Tacoma’s operations center. The Operations Communication Center is monitored round the clock, 365 days a year, and handles all calls from airlines. The most common maintenance issues are the result of PCA hose mishandling and damage to the connectors. The maintenance team stocks extra hoses in case of equipment failure. In addition to equipment mishandling, other causes for less-than-optimal utilization include the unwillingness of some carriers to connect to the PCA system. These carriers—particularly Asian carriers with short turn times—prefer to keep the APU running. Carriers that regularly use the hardstands also use APUs or mobile diesel units.



Figure 34. Aerial view of Seattle–Tacoma International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 4C, Mixed/Marine Large hub, primary, commercial - Passengers: 46,934,619 - Passenger growth: 2.6% - Cargo weight: 425,856 metric tons - Cargo growth: 16.22% - Number of airlines serving: 34 <i>2017 data provided by the airport.</i>	- There are 66 to 72 operational gates with jet bridges (fluctuation due to construction), and all gates are owned by the airport. - All jet bridges are equipped with electric PCA from one central cooling–heating plant and 400 Hz ground power. Additional natural gas–powered heating plants provide warm air, as well. - A hardstand terminal with six gates is not equipped with electric PCA and 400 Hz ground power. - There are a few portable PCA and diesel-powered GPU that are only used in emergency situations.
Major Tenants	Regulatory Issues
- Passenger airlines: Alaska Airlines, Delta Air Lines, Southwest Airlines, and United Airlines - Cargo: ABX Air, Alaska Airlines, FedEx, and Air Transport International <i>Passenger and cargo carriers with greatest market share listed</i>	- VALE status: Currently in attainment and not eligible. However, the airport was eligible in the past. - Current NAAQS status: Attainment - VALE participation: FY 2010 and FY 2011, \$18.3 million and \$3.6 million, respectively, to purchase PCA system.

Figure 34A. Seattle–Tacoma International Airport specifications.

Drivers for Installation

- Protect air quality through a project expected to prevent emissions of 2,900 tons of nitrogen oxides throughout the equipment’s useful life (FAA 2017).
- Reduce airport carbon footprint: The PCA system prevents 40,000 tons of CO₂ emissions annually when fully utilized (Port of Seattle 2017).
- Conserve fuel: The PCA system saves 5 million gallons of fuel each year (Port of Seattle 2017).
- Enhance passenger comfort.
- Foster community support and interest in Port of Seattle environmental management.
- Decrease noise pollution from parked aircraft (Port of Seattle 2017).



Figure 35. Clockwise from top left: Ice storage in central plant, central plant pumps, kinked PCA hose, and aircraft connected to PCA and ground power (Source: Port of Seattle).

Finance Strategy

- Leverage VALE grants.
- The Port of Seattle conducted a cost–benefit analysis and determined that the PCA system saves \$15 million annually in fuel costs for airlines, with a 2-year return on investment (Port of Seattle 2017).
- Costs are included in rates and charges that the airport charges the airlines.

Planning and Policy

- The airport worked with the airlines to get support for VALE grant.
- Some airlines have corporate policies to plug into PCA as soon as possible. These airlines track APU use and determine reasons for use.

Tracking and Data Collection on Utilization

- The building automation system monitors the PCA system and allows the airport to make adjustments for optimal performance (i.e., temperature of air, aircraft cabins, and when the PCA is on or off).

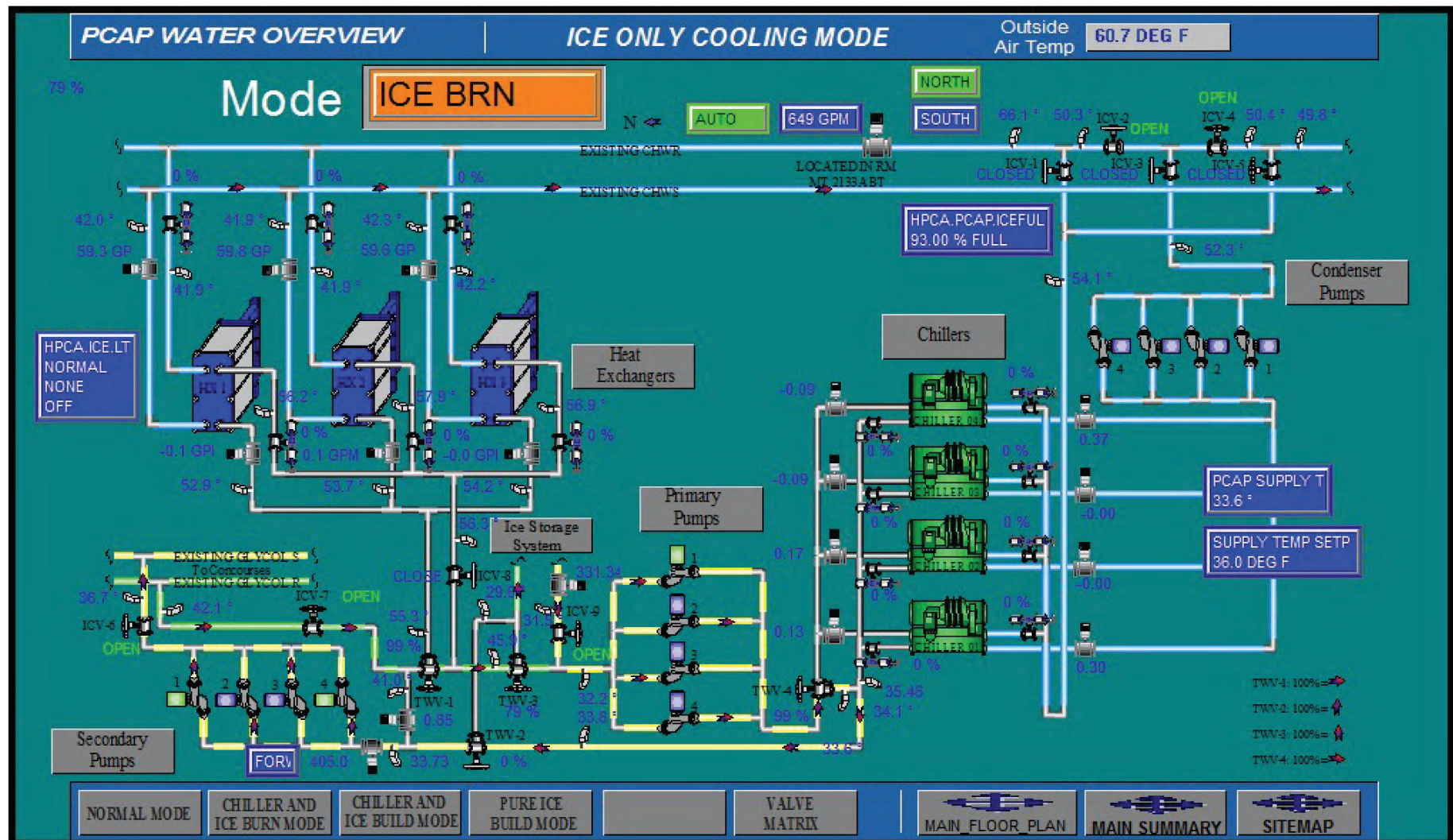


Figure 36. Central plant monitoring software display.

- Challenges related to aligning data from the building automation system with the actual time the aircraft remain at the gates and the inability to track APU use limits overall utilization calculations.
- The SafeDock system exists at six gates, expanding use to additional gates to provide data on when airlines are at gates.

Lessons Learned and Best Practices

- Use of building automation system to monitor the PCA system is feasible because of the central system, and it allows the airport to better adjust the PCA to meet operating conditions and the needs of aircraft.
- Operator error is the largest challenge inhibiting better utilization. Many issues stem from PCA hoses being improperly laid out and connected to the aircraft or pilots leaving APUs running on short turn times.
- Consistent training is key.
- The gates are able to accommodate various sizes of aircraft by varying the speed of the variable frequency drive on the fan motor, (i.e., adjusting the air flow rate to match the requirements of both narrow- and wide-body aircraft. Therefore, hoses must be long enough to accommodate both types of aircraft. While the variable frequency drive on the fan motor provides flexibility in use of the gates, it aggravates the issues with hoses noted above.

6.14 Tallahassee International Airport (TLH), Tallahassee, Florida

Background

Located in Florida's capital city, the Tallahassee International Airport has a hot and humid climate, and properly conditioned aircraft cabins and jet bridges are essential at the airport. The airlines serving Tallahassee International strongly support the use of electric PCA and ground power to ensure passenger comfort and have backup diesel-powered mobile units to use when the PCA and ground power units are out of service.

The airport has eight gates with jet bridges, and all are equipped with electric PCA (point-of-use units) and 400 Hz ground power (Figure 37). The equipment was originally installed around 2005. Reliability of the equipment is mixed, with equipment from certain manufacturers requiring more maintenance than other models. For example, vents on top of some of the ground power units let in water during precipitation events, which are frequent in North Florida, and the water causes the transformers to break. The airport is currently planning to replace all eight jet bridges, including the electric PCA and 400 Hz ground power equipment. This project will be funded through a state grant from the Florida Department of Transportation and passenger facility charges and will occur over several years. The airport is considering submetering for newly installed equipment.

Maintenance of the systems is handled in house by Tallahassee International staff. The department has staff on site during normal business hours and on call during nighttime hours and on weekends. Airport maintenance staff use a tracking system to document historical replacement of spare parts and corrective actions taken to maintain systems. As a best practice, maintenance keeps a stock of spare parts on site as spare parts can take time to obtain. The maintenance budget is generally sufficient to handle the needed repairs; although, at times, the airport reports that staff are overloaded with work orders. The utilization of electric PCA and 400 Hz ground power is not tracked by the airport (Figure 37A). But staff observe that when gate electrification equipment is in service, the aircraft connect. (When gate electrification equipment is out of order, airlines use diesel-powered mobile units.)



Figure 37. Aerial view of Tallahassee International Airport.

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 2A, Hot/Humid Non-hub, primary, commercial • Passengers: 732,235 • Passenger growth: 2.56% • Number of airlines serving: Three <i>2017 data provided by the airport.</i>	• There are eight operational gates with jet bridges, all owned by the airport. • All gates are equipped with electric PCA and 400 Hz ground power. • The airport owns one combination 28 V and 400 Hz ground power diesel-powered mobile unit; airlines own diesel-powered mobile units. • Utilization rate is not systematically tracked.
Major Tenants	Regulatory Issues
• Passenger airlines: American Airlines, Delta Air Lines, and Silver Airways • Cargo: FedEx	• VALE status: Not eligible • Current NAAQS status: Attainment

Figure 37A. Tallahassee International Airport specifications.

The airlines have a mix of in-house employees servicing aircraft and third-party contracted ground crews. Anecdotally, airport staff have observed that third-party contractors perform better than airline staff.

Challenges to utilization include equipment mishandling by ground crews that results in the PCA or ground power equipment being out of service; for example, when PCA hoses or ground power cables are damaged from being dragged across the pavement or run over with jet bridges. The airport has a mechanism to charge airlines for the repair or replacement of equipment that has been damaged from improper use, as opposed to normal wear. In addition, the jet bridges are not air conditioned. This lack of air conditioning causes cool air from the aircraft to flow into the jet bridge, which inhibits the ability of PCA to cool the aircraft. The airport is considering this factor in the jet bridge replacement project.

Drivers for Installation

- The airport considers electric PCA and ground power to be a best practice and has airline support.

Finance Strategy

- The state will fund new jet bridges through the Florida Department of Transportation and passenger facility charges.

Planning and Policy

- Jet bridges and equipment are nearing the end of useful life, and a replacement project is planned.
- The airport charges airlines for repairs, which provides an incentive to maintain equipment.

Tracking and Data Collection on Utilization

- Newly installed jet bridges will have equipment for tracking hours of use.
- Flights that are diverted through the airport may run APUs.

Lessons Learned and Best Practices

- Maintain stock of spare parts on site to avoid delays.
- Certain PCA and ground power equipment models are less reliable and require more maintenance.

6.15 Zurich International Airport (ZRH), Zurich, Switzerland

Background

Zurich International Airport in Switzerland is the only non-U.S. airport included as a case study and provides an interesting contrast in the types of equipment, utilization tracking procedures, and APU use restrictions in place.

Switzerland has stringent environmental regulations, but there are several locations on the airport's property that do not meet national air quality standards for NO₂, PM, and ozone (Fleuti and Ruf 2018). The airport has had air quality mitigation measures in place since the early 1990s and considers the provision of electrical PCA and 400 Hz ground power to be a critical component of their environmental management efforts (Figure 38). In addition, the airport requires airlines to use the electric PCA and 400 Hz ground power systems as long as they are available and in good working order—or, alternatively, the mobile units—and only rely on APUs in cases when neither is an option (Fleuti and Ruf 2018) (Figure 38A). Airport regulations stipulate that aircraft APUs only be used to start the aircraft engine and be turned on no earlier than 10 minutes before departure from the gate.

Zurich International Airport has both a central chiller plant for the PCA system and central 400 Hz transformers for ground power with point-of-use hookups at the gates (Figure 39). The heating supply for PCA in colder months is provided by the airport's heating plant. Many gates have equipment necessary to service different sizes of aircraft and can, therefore, be flexible.

The airport routinely reports achieving a 99.7 percent serviceability rate (meaning that systems are available and are in an operational and usable state), with high attainment, and that ground crews have consistent ability to connect the aircraft to ground power within 30 to 40 seconds of the aircraft parking (Figure 40). This achievement is due, in part, to the airport's plant system, which includes a monitoring and control system and a dashboard to monitor the status of the entire system. The dashboard is used by technical staff to identify system performance, use, and direct maintenance activities. Staff can see when equipment is in use or when a failure has occurred. Ambient and aircraft cabin temperatures are also monitored so that air



Figure 38. PCA hoses at Zurich International Airport
(Source: Zurich International Airport).

Airport Size and Geography	Equipment and Utilization
ASHRAE Climate Zone: 5A, Cool/Humid - Passengers: 29,396,094 - Passenger growth: 6.3% - Cargo weight: 490,452 tons - Cargo growth: 13.1% - Number of airlines serving: 68 2017 data provided by the airport.	- There are 53 pier stands (terminal-connected jet bridges). - All 53 pier stands are equipped with electric PCA and 400 Hz ground power. - There are 15 open stands (i.e., remote aircraft parking positions) with electric 400 Hz ground power. - Flughafen Zurich AG, the airport owner and operator, owns and maintains equipment. - There are 45 mobile, diesel-powered GPU units, and approximately four mobile PCA units are available.
Major Tenants	Regulatory Issues
- Passenger airlines: Swiss International Air Lines, Edelweiss Air, Air Berlin, Eurowings, and easyJet - Cargo: dnata Switzerland and Cargologic	- Various locations on airport property exceed Switzerland air quality standards for NO₂, PM₁₀, and ozone. - Zurich International mandates that airlines use PCA and 400 Hz ground power when available and serviceable.

Figure 38A. Zurich International Airport specifications.

temperature can be adjusted accordingly (Figure 41). Maintenance crews can deploy quickly to ramps that are not using the system to determine the cause, (i.e., kinked hose, aircraft cannot accept 400Hz, and so on).

The airport has created a variety of resources for airline personnel to reference, including brochures, flyers, and checklists. Brochures cover aircraft ground energy systems at the airport; flyers provide similar information designed for pilots and airline headquarters staff; and a checklist is intended for cockpit crew members, who are responsible for properly connecting the aircraft itself. In addition, the airline has held workshops with airlines to exchange information and determine the best ways to improve services and systems. The airport also communicates directly with ground crew on the proper use of the gate electrification equipment.

To support other airports, Zurich International contributed to the development of AGES-S, available through Airports Council International–World. The Excel-based tool



Figure 39. Aircraft connected to PCA hose and ground power cable at gate (Source: Zurich International Airport).

allows airports to assess the economic and environmental benefits of using electric PCA and 400 Hz ground power instead of aircraft APU under various scenarios. Airports can input their own information—including cost savings and emissions reductions—so that the tool will provide tailored outputs. The tool is useful for conducting cost–benefit analyses but does not assist with utilization tracking.

Drivers for Installation

- The main motivating factor was the desire to protect local air quality and reduce criteria pollutants and greenhouse gas emissions.
- The stringent regulatory environment in Switzerland, combined with the anticipation that ultrafine PM regulation is on the horizon in Europe, add to motivation for gate electrification.
- Reduction in noise on the apron from minimizing APU usage is an additional benefit.



Figure 40. Ground crew plugging in power cable (Source: Zurich International Airport).

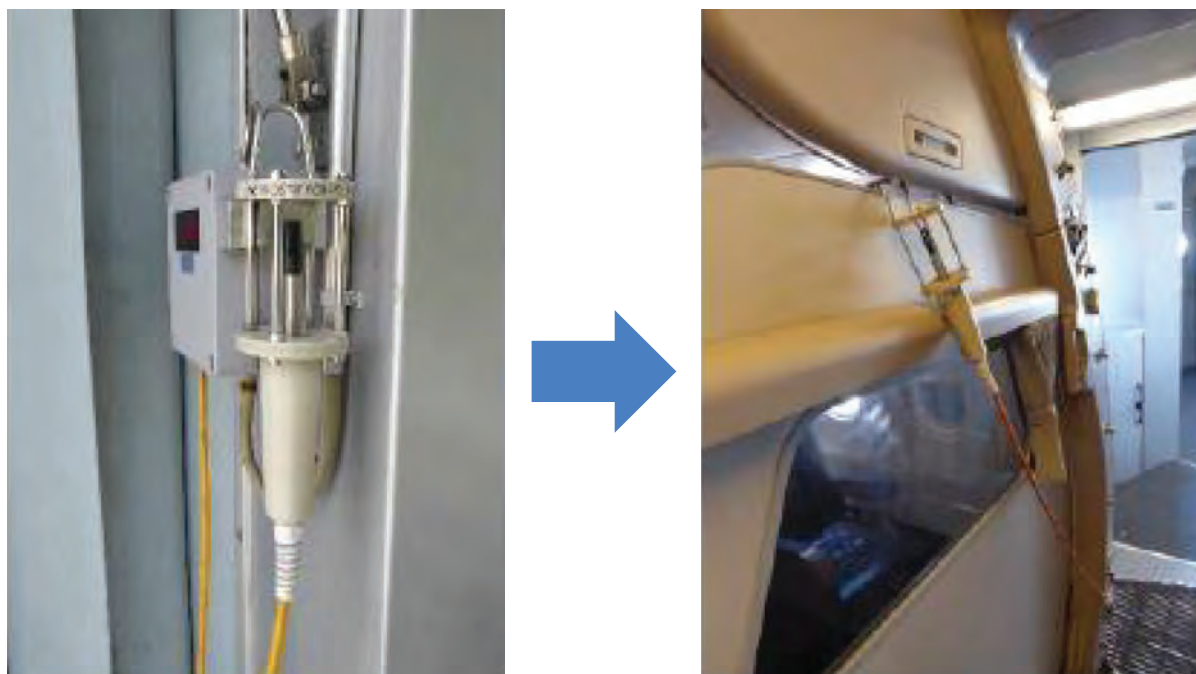


Figure 41. Initial position of temperature sensor on jet bridge (left) and its position in the aircraft cabin (right) (Source: Zurich International Airport).

Finance Strategy

- Flughafen Zurich AG funded the system acquisition and installation of the equipment.
- The airport owns, operates, and maintains the system.
- Airlines are charged for use of 400 Hz ground power and PCA use based on aircraft type and length of time connected to PCA and ground power systems. Rates are both hourly and 2-hour flat rates.
 - Although the use of electric PCA and 400 Hz ground power saves airlines money on fuel, there is sometimes a disinclination on the part of airline station managers to use the gate electrification equipment because the fees for its use come out of the station budget, as opposed to the corporate fuel budget.

Planning and Policy

- Airport policy requires that all aircraft connect to PCA and ground power systems if they are available and in service. If these systems are not in service, then mobile units should be used. If mobile units are unavailable, then APUs can be used. There are a few limited exceptions to this rule.
- There are mechanisms in place for the airport to further investigate noncompliance with the airport's APU use policy, including communicating with chief pilots and reporting noncompliance to Swiss regulators.

Tracking and Data Collection on Utilization

- The airport has an APU violation report form and logs all incidents of noncompliance, which normally occur only a few times annually.
- The airport's building information management system captures information on equipment use (e.g., time, electricity, and natural gas consumed), as well as maintenance records.
- The equipment is in service and available over 99 percent of the time.

Lessons Learned and Best Practices

- The airport provides support to airlines, including brochures on aircraft ground energy systems at Zurich International, flyers distributed to pilots and airline headquarters staff, and a one-page checklist for cockpit crews concerning connection to systems and on APU restrictions.
- A spare parts inventory of components most likely to need replacement—such as PCA hoses, segments, and connections—is useful, since PCA hose damage is the largest maintenance issue.
- Airport staff provide training, including workshops, to ground handlers to reinforce proper procedures for using PCA and 400 Hz ground power equipment.
- The storage of 400 Hz ground power cables in underground pits helps prevent cable damage and declutters the ramp.



Bibliography

- Abdel-Fadil, R., A. Eid, and M. Abdel-Salam. Electrical Distribution Power Systems of Modern Civil Aircrafts. Presented at 2nd International Conference on Energy Systems and Technologies, Cairo, Egypt, 2013. https://www.researchgate.net/publication/235932771_Electrical_distribution_power_systems_of_modern_civil_aircrafts.
- Aero Systems Engineering, Inc. *Feasibility Study: Pre-conditioned Air, Salt Lake City International Airport Proposed South Concourse Gates 1–36, 38 & 40*. Marietta, Ga., 2013.
- Airport Carbon Accreditation. Accredited Airports Across the World, North America. 2018. <https://www.airportcarbonaccreditation.org/airport/participants/north-america.html>.
- Airports Council International–Europe. *Airport Carbon Accreditation Annual Report 2017–2018*. Geneva, Switzerland, 2018. <https://airportcarbonaccreditation.org/component/downloads/downloads/132.html>.
- Airports Council International. Aircraft Ground Energy System–Simulator (AGES-S) v.1. 2018. <https://aci.aero/about-aci/priorities/environment/ages-s/>. Accessed Oct. 23, 2018.
- Air Transport Action Group. *Aviation: Benefits Beyond Borders*. Geneva, Switzerland, 2018. <https://www.atag.org/our-publications/latest-publications.html>.
- American Airlines. *2017 Corporate Responsibility Report*. 2017. http://s21.q4cdn.com/616071541/files/doc_downloads/crr/CRR-Report-2017.pdf.
- The Boeing Company. Airports with Noise and Emissions Restrictions. 2018. <http://www.boeing.com/commercial/noise/list.page>.
- California Air Resources Board. 2009. *California Code of Regulations*. Title 17, §95101. 2009. https://www.arb.ca.gov/cc/reporting/ghg-rep/regulation/mrr-2016-unofficial-2017-10-10.pdf?_ga=2.22897531.1520631629.1552073070-1816738388.1552073070.
- Cavotec. Skyway Terminal & GSE Utilization. PowerPoint presentation. 2018.
- CDM Federal Programs Corporation, KB Environmental Sciences, Inc., and Ricondo and Associates, Inc. *ACRP Report 78: Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial*. Transportation Research Board of the National Academies, Washington, D.C., 2012. <http://dx.doi.org/10.17226/22681>.
- Dallas–Fort Worth International Airport. *2017 Environmental, Social and Governance Report*. 2018. https://www.dfairport.com/cs/groups/webcontent/documents/webasset/p2_950004.pdf. Accessed Nov. 24, 2018.
- Energy and Environmental Analysis, Inc. *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation*. Memorandum. Arlington, Va., 1995. <http://www.forces.org/evidence/download/airplane.pdf>.
- Environmental Protection Agency, Part II: 40 CFR Parts 86, 87, 89 et al. Mandatory Reporting of Greenhouse Gases: Final Rule. *Federal Register*, Vol. 74, No. 209, Fri., Oct. 30, 2009, pp. 56260–56519. <https://www.govinfo.gov/content/pkg/FR-2009-10-30/pdf/E9-23315.pdf>.
- Environmental Protection Agency. Reviewing National Ambient Air Quality Standards (NAAQS): Scientific and Technical Information. 2017. <https://www.epa.gov/naaqs>.
- Environmental Science Associates, AERO Systems Engineering, Inc., Synergy Consultants, Inc., and Wyle, Inc. *ACRP Report 64: Handbook for Evaluating Emissions and Costs of APU's and Alternative Systems*. Transportation Research Board of the National Academies, Washington, D.C., 2012. <https://doi.org/10.17226/22797>.
- FAA. *Voluntary Airport Low Emission Program Technical Report*, Version 7. Report DOT/FAA/AR-04/37. U.S. Department of Transportation, 2010. https://www.faa.gov/airports/environmental/vale/media/vale_techreport_v7.pdf.
- FAA. *United States Aviation Greenhouse Gas Emissions Reduction Plan*. U.S. Department of Transportation, 2012. https://www.faa.gov/about/office_org/headquarters_offices/apl/enviro_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf.

- FAA. *Airport Improvement Program Handbook*. FAA Order 5100.38D U.S. Department of Transportation, 2014. https://www.faa.gov/airports/aip/aip_handbook/media/AIP-Handbook-Order-5100-38D.pdf.
- FAA. *Environmental Impacts: Policies and Procedures*. Order 1050.1F U.S. Department of Transportation, 2015A. https://www.faa.gov/documentlibrary/media/order/faa_order_1050_1f.pdf.
- FAA. *Aviation Emissions and Air Quality Handbook*, Version 3, Update 1. U.S. Department of Transportation, 2015B. https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/airquality_handbook/media/Air_Quality_Handbook_Appendices.pdf.
- FAA. *United States Aviation Greenhouse Gas Emissions Reduction Plan*. U.S. Department of Transportation, 2015C. https://www.icao.int/environmental-protection/Lists/ActionPlan/Attachments/30/UnitedStates_Action_Plan-2015.pdf.
- FAA. Voluntary Airport Low Emissions (VALE) Program: Federal Support for Clean Air and Airport Emissions Reduction Initiatives. U.S. Department of Transportation, 2017. <https://www.faa.gov/airports/environmental/vale/media/VALE-brochure-2017.pdf>.
- FAA. Voluntary Airport Low Emissions Program Grant Summary: Fiscal Year (FY) 2005–2018. U.S. Department of Transportation, 2018. <https://www.faa.gov/airports/environmental/vale/media/VALE-grant-summary.pdf>.
- Fleuti, E., and C. Ruf. *Aircraft Ground Energy Systems at Zurich Airport*, Version 2. Flughafen Zurich AG, Zurich, Switzerland, 2013.
- Fleuti, E., and C. Ruf. *Aircraft Ground Energy Systems at Zurich Airport*, Version 3. Flughafen Zurich AG, Zurich, Switzerland, 2018. https://www.zurich-airport.com/~media/flughafenzh/dokumente/das_unternehmen/laerm_politik_und_umwelt/luft/2018_zrh_aircraft-ground-energy-system_20180214.pdf.
- Golder Associates. *Pre-Conditioned Air and Ground Power Unit Usage at Canadian Airports*. Report No. 1415067. 2015.
- International Civil Aviation Organization. *Operational Opportunities to Minimize Fuel Use and Reduce Emissions*. Montreal, Quebec, Canada, 2003.
- International Civil Aviation Organization. *Airport Air Quality Manual*, 1st edition. Montreal, Quebec, Canada, 2011. <https://www.icao.int/environmental-protection/Documents/Publications/FINAL.Doc%209889.1st%20Edition.alltext.en.pdf>.
- International Civil Aviation Organization. *ICAO Environmental Report 2016: Aviation and Climate Change*. Montreal, Quebec, Canada, 2016. <https://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf>.
- KB Environmental Sciences, Inc. *ACRP Report 149: Improving Ground Support Equipment Operational Data for Airport Emissions Modeling*. Transportation Research Board of the National Academies, Washington, D.C., 2015. <http://dx.doi.org/10.17226/22084>.
- Kim, B., K. Nakada, R. Wayson, S. Christie, C. Paling, M. Bennett, D. Raper, V. Raps, J. Levy, and C. Roof. *ACRP Report 135: Understanding Airport Air Quality and Public Health Studies Related to Airports*. Transportation Research Board of the National Academies, Washington, D.C., 2015. <http://dx.doi.org/10.17226/22119>.
- Kwan, J. S. W., and S. J. E. Yang. Auxiliary Power Unit Noise of Boeing B737 and B747 Aircraft, 1992. <http://adsabs.harvard.edu/abs/1992STIA...9588468K>.
- National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Northeast RCC CLIMOD 2. <http://climod2.nrcc.cornell.edu/>.
- Nordstrom, R. New Hardstand Terminal at Sea-Tac Redefines Hardstand Operations. *Airport Improvement*. November–December 2018. <https://airportimprovement.com/article/new-hardstand-terminal-sea-tac-redefines-hardstand-operations>.
- Philadelphia International Airport. *Philadelphia International Airport Rules and Regulations Manual*, Section 3: Aircraft Operations. 2012, pp. 3-1–3-18. <https://www.phl.org/Documents/RulesRegs/PHLRRSec3.pdf>.
- Port of Portland. *Environmental Report 2016/17*. 2017. http://cdn.portofportland.com/pdfs/POP_ENV_report.pdf.
- Port of Seattle. Pre-Conditioned Air. 2017. <https://www.portseattle.org/projects/pre-conditioned-air>.
- San Diego County Regional Airport Authority, and the Attorney General of California. *Memorandum of Understanding Between the Attorney General of the State of California and the San Diego County Regional Airport Authority Regarding the San Diego International Airport Master Plan*. 2008. http://ag.ca.gov/globalwarming/pdf/San_Diego_Airport_Agreement.pdf.
- Scholz, D. An Optimal APU for Passenger Aircraft. Presented at 5th CEAS Air and Space Conference, Delft, Netherlands, 2015.
- Sikorski, E. Air-Conditioning of Parked Aircraft by Ground-Based Equipment. Presented at International Refrigeration and Air Conditioning Conference, West Lafayette, Indiana, 2010. <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?referer=https://www.bing.com/&httpsredir=1&article=2085&context=iracc>.
- Southwest Airlines. *2015 Southwest Airlines One Report*. 2015. <http://southwestonereport.com/2015/#/report-page>.
- Southwest Airlines. *2016 Southwest Airlines One Report*. 2016. <http://southwestonereport.com/2016/about-the-report/>.

- Southwest Airlines. *2017 Southwest Airlines One Report*. 2017. http://southwestonereport.com/2017/content/uploads/2018/06/2017_SouthwestAirlinesOneReport-1.pdf.
- Stantec Consulting, Ltd. *Transport Canada: Alternative Systems to Reduce Aircraft Auxiliary Power Unit Emissions*, 2016.
- Tam, C. K. W., N. N. Pastouchenko, J. Mendoza, and D. Brown. Combustion Noise of Auxiliary Power Units. Presented at 11th AIAA/CEAS Aeroacoustics Conference, Monterey, Ca., 2005. <https://arc.aiaa.org/doi/abs/10.2514/6.2005-2829>.
- Tetra Tech EBA, Inc. *Study of Best Practices and Procedures, Policies and Regulations Relating to Auxiliary Power Units (APU) and Ground Support Equipment (GSE)*. Ottawa, Ontario, Canada, 2014.
- Tetra Tech EBA, Inc. *Feasibility of Alternative Energy Conversion of Ground Support Equipment (GSE) at Canadian Airports*. Ottawa, Ontario, Canada, 2016.
- Transport Canada. *Canada's Action Plan to Reduce Greenhouse Gas Emissions from Aviation: Section 6.3 Airport Ground Operations and Infrastructure Use*. 2012. <https://www.tc.gc.ca/eng/policy/acs-reduce-greenhouse-gas-aviation-menu-3007.htm#s63>.
- United Airlines, Inc. Fuel Efficiency and Emissions Reduction. 2018. <https://www.united.com/ual/en/us/fly/company/global-citizenship/environment/fuel-efficiency-and-emissions-reduction.html>.
- Wade, M. D. *Aircraft/Auxiliary Power Units/Aerospace Ground Support Equipment Emission Factors*. 2002.
- World Meteorological Organization. *WMO Statement on the State of the Global Climate in 2018*. 2018. https://library.wmo.int/doc_num.php?explnum_id=5789.



APPENDIX A

Acronyms and Glossary

Acronyms

A4A	Airlines for America
ACI	Airports Council International–World
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
AEDT	Aviation Environmental Design Tool
AHU	air handling unit
AIP	Airport Improvement Program
ALPA	Air Line Pilots Association
APU	auxiliary power unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATL	Hartsfield–Jackson Atlanta International Airport
BOS	Boston Logan International Airport
BTV	Burlington International Airport
CAA	Clean Air Act
CAAFI	Commercial Aviation Alternative Fuels Initiative
CDD	cooling degree days
CMMS	computerized maintenance management system
CO ₂	carbon dioxide
CORSIA	Carbon Offset and Reduction Scheme for International Aviation
DEN	Denver International Airport
DFW	Dallas–Fort Worth International Airport
FAA	Federal Aviation Administration
FDOT	Florida Department of Transportation
GHG	greenhouse gas

GPU	ground power unit
GSE	ground support equipment
HDD	heating degree days
hr	hour
HVAC	heating, ventilation, and air conditioning
Hz	hertz
ICAO	International Civil Aviation Organization
MCI	Kansas City International Airport
MEM	Memphis International Airport
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
PCA	preconditioned air
PDX	Portland International Airport
PFC	passenger facility charge
PHX	Phoenix Sky Harbor International Airport
PIT	Pittsburgh International Airport
POU	point of use
SAN	San Diego International Airport
SEA	Seattle–Tacoma International Airport
SMF	Sacramento International Airport
TIM	time in mode
TLH	Tallahassee International Airport
TRB	Transportation Research Board
UPS	United Parcel Service
USEPA	United States Environmental Protection Agency
VALE	Voluntary Airport Low Emissions
ZRH	Zurich International Airport

Glossary

Air handling unit (AHU): An air handling unit is a system or device used to circulate, clean, heat, cool, and (de)humidify air as part of a larger heating, ventilation, and air conditioning (HVAC) system.

Airport Improvement Program (AIP): The Airport Improvement Program is authorized by Congress and administered by the FAA to provide grant funding to entities for the planning and development of public-use airports. To be eligible, airports must be listed in the National Plan of Integrated Airport Systems.

Air pollution: The presence of one or more substances, chemicals, or particulates in the air in sufficient quantities to cause negative impacts to human health, welfare, flora, and fauna. The substances or chemicals that cause harm are air pollutants.

Air Transport Action Group (ATAG): A global commercial aviation industry coalition comprised of member companies formed to advocate for common positions.

Auxiliary Power Units (APU): Small turbine engines on aircraft (in addition to the main engines) that are used to provide power to start the main engines and to provide power to onboard electrical systems and cabin air conditioning (and heating) when main engines are off.

Carbon dioxide (CO₂): Carbon dioxide (CO₂) is a colorless gas comprised of one carbon atom and two oxygen atoms. CO₂ is produced primarily from the combustion of fossil fuels and, to a lesser extent, from naturally occurring sources such as volcanoes and the decay of organic matter. It is one of the primary greenhouse gases responsible for climate change.

Carbon monoxide (CO): One of the six criteria pollutants, carbon monoxide is a chemical product of incomplete combustion. CO is produced by motor vehicles and equipment with internal combustion engines. At high concentrations, CO can inhibit the oxygen-carrying capacity of hemoglobin in the blood, which is a health concern particularly for vulnerable populations (for people with certain other health conditions).

Carbon Offset and Reduction Scheme for International Aviation (CORSIA): A program developed by the United Nations International Civil Aviation Organization (ICAO) to reduce the growth of greenhouse gas emissions from international aviation.

Clean Air Act (CAA): A federal law that regulates air quality and the emission of air pollutants. The CAA was first passed by Congress in 1967 and required that the U.S. government develop air quality regulations and set criteria to protect the “public health and welfare”. The CAA provided the authority for the U.S. Environmental Protection Agency to develop the National Ambient Air Quality Standards (NAAQS) regulating six criteria pollutants.

Commercial Aviation Alternative Fuels Initiative (CAAFI): A coalition comprised of airlines, airports, the Federal Aviation Administration, and aerospace manufacturers to advance the development of sustainable alternative aviation fuels through research, collaboration, and policy advocacy.

Cooling Degree Days (CDD): A degree day is the difference in temperature between the average outdoor temperature for a given location over a 24-hour period and a standard base temperature. A cooling degree day is a measure of how much energy is needed to cool a building over a 24-hour period.

Criteria Pollutant: A pollutant determined by the U.S. EPA to be hazardous to human health. The criteria pollutants are regulated under the CAA and the NAAQS. There are six criteria pollutants, including ozone, particulate matter, lead, carbon monoxide, nitrogen dioxide, and sulfur dioxide.

Emissions: A release or discharge of a substance (in this context an air pollutant) into the environment.

Go/No Go Gauge: In general, a Go/No Go gauge is an inspection device used to test certain components (i.e., pins, hardware, and so on) to ensure they meet acceptable standards or specifications.

Greenhouse Gases (GHG): Gases that trap heat in the atmosphere, creating a “greenhouse effect” on Earth. GHGs include carbon dioxide, methane, nitrous oxide, and fluorinated gases. Often greenhouse gases are converted to “carbon dioxide equivalent” (i.e., for a given amount of a particular GHG, the carbon dioxide equivalent is a measure of the amount of carbon dioxide with the same global warming potential).

Ground power units (GPU): Equipment that supplies power to aircraft on the ground in order to run electrical systems onboard the aircraft while the engines are off. GPUs can be mobile (battery or fossil-fuel powered), or provide electricity from the airport’s infrastructure (electricity from the grid).

Ground support equipment (GSE): Vehicles and equipment associated with the servicing of aircraft during the airport turnaround process (i.e., ground operations that occur from the time the aircraft arrives at the gate or remote parking position to the time the aircraft leaves the gate). GSE includes fueling trucks, baggage carts, catering vehicles, water carts, equipment used for loading and unloading passengers, ground power units, etc.

Heating Degree Days (HDD): A degree day is the difference in temperature between the average outdoor temperature for a given location over a 24-hour period and a standard base temperature. A heating degree day is a measure of how much energy is needed to heat a building over a 24-hour period.

Hertz (Hz): A unit of measurement of frequency, with one hertz equaling one cycle per second. 400 Hz is a type of frequency within Alternating Current (AC) electrical power, and is commonly used for powering systems on aircraft.

Load Bank: A load bank is a device used to test power sources by mimicking the electrical load of the equipment that will ultimately be connected to the power source and measuring the output of the power source. This tests the ability of the source to handle the voltage of the system.

National Ambient Air Quality Standards (NAAQS): Air quality regulations developed by the U.S. EPA under the Clean Air Act designed to protect the health and welfare of the population. Primary standards are developed to protect human health (particularly vulnerable populations), and secondary standards are designed to protect property. The NAAQS are periodically updated.

National Environmental Policy Act (NEPA): A federal law that established the Council on Environmental Quality (CEQ) and requires federal agencies to consider the environmental impacts of their actions and alternatives.

Passenger Facility Charge (PFC): The Passenger Facility Charge program provides a mechanism for publicly owned, commercial service airports to collect fees up to \$4.50 per enplaned passenger per

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segment (up to two segments for a one way trip or up to four segments for a round-trip ticket). Airport owners and operators can use fees collected under this program to fund FAA-approved projects, including safety, capacity, security, and noise mitigation or air service-related projects.

Preconditioned Air (PCA): Equipment that supplies pre-cooled or heated air to aircraft that are on the ground. PCA can be delivered via central HVAC systems, point-of-use systems (typically attached to a jet bridge), or a fossil-fuel powered mobile unit.

Voluntary Airport Low Emissions Program (VALE): A program administered by the Federal Aviation Administration to assist airport sponsors to meet their air quality responsibilities under the Clean Air Act. Eligible airports include those in designated nonattainment or maintenance areas for one of the six criteria pollutants regulated by the NAAQS. Through VALE, airports can apply for grant funding from the Airport Improvement Program (AIP) or use Passenger Facility Charges (PFCs) to finance the purchase of low emission vehicles and related fueling/charging infrastructure, gate electrification equipment, and other airport air quality improvements.



APPENDIX B

Airport Survey Summary

The research team administered an electronic survey via Survey Monkey (online survey software) to solicit information from a broad range of airports regarding the challenges to optimal utilization of gate electrification systems. The airport survey was undertaken to supplement the findings from the in-person focus group meetings and the web-enabled case study interviews. The survey was distributed to airports via airport trade associations (ACI-NA and AAAE) as well as distributed directly to airports by members of the research team. A total of 34 airports responded to the survey, six of which also participated as either a focus group or case study airport; therefore, the survey was successful in obtaining information from an additional 28 airports not already covered by the focus groups and case studies. Some of the airports skipped certain questions; therefore, the summary data below for certain questions contain results with fewer than 34 responses.

The survey questions were developed based on initial focus group and case study stakeholder input. The survey was also reviewed and approved by the project panel. It included questions covering electric preconditioned air (PCA) units and electric ground power systems (collectively referred to as gate electrification systems), utilization tracking practices, maintenance of systems, equipment procurement, regulatory requirements, and stakeholder policies. This appendix provides a description of the methodology and assumptions and the summary of the responses received.

1. Survey Respondents Summary Data

This section covers aggregated demographic characteristics of the respondent airports, including airport hub sizes, climatic zones, National Ambient Air Quality Standards (NAAQS) attainment status, and VALE eligibility (U.S. airports only).

Respondent Hub Sizes

Survey respondents represent a variety of hub sizes. As presented in Figure 42, 23 percent are large hub, 24 percent are medium hub, 29 percent are small hub, 15 percent are non-hub, and 9 percent are Canadian.

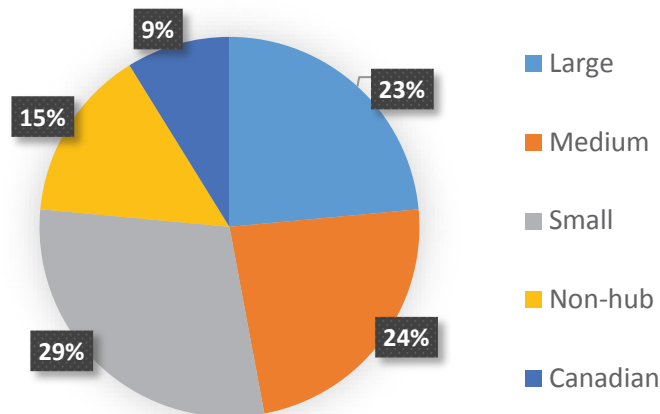


Figure 42. Percentage of respondents representing each hub size.

Respondent Climatic Zones

Respondent airports are located across the U.S. and Canada and cover 7 ASHRAE climatic zones. ASHRAE standards are intended to provide climatic data for use in building design and equipment standards.

Figure 43 presents the percentage of respondents that fall into each thermal climate zone represented, Zones 1-7. ASHRAE zones are denoted by a number (based on heating and cooling degree days) and a letter, which represents the subtype: Humid (A), Dry (B) or Marine (C) (Subtype is determined based on annual mean temperature and precipitation data). Figure 44 shows the distribution of airports across the climate zones and subtype.

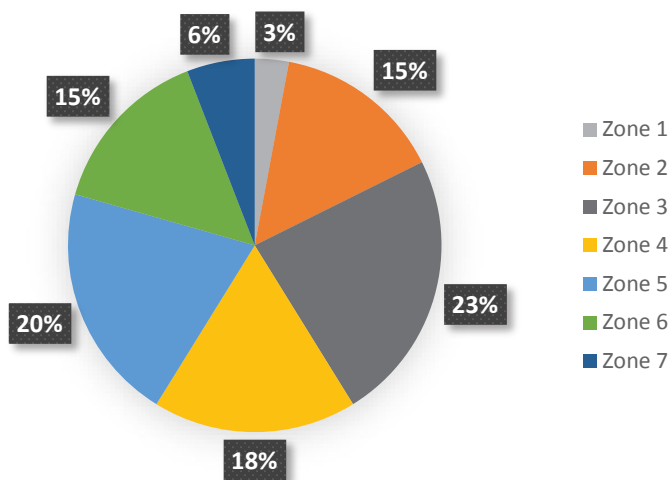


Figure 43. Percentage of respondents representing ASHRAE Thermal Zones 1-7.

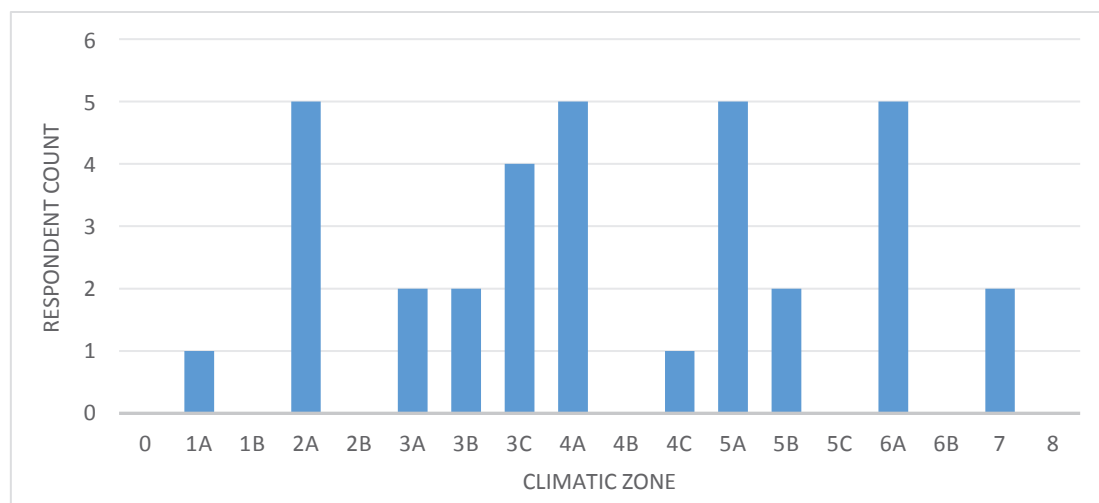


Figure 44. Number of respondents in each ASHRAE moisture zone (A= Humid, B=Dry, C= Marine).

NAAQS Status of Respondents

The survey included a question on the NAAQS status to determine which airports are in nonattainment or maintenance zones for the six criteria pollutants (ground level ozone, carbon monoxide, particulate matter, nitrogen dioxide, sulfur dioxide, and lead) regulated under the Clean Air Act by the U.S. EPA (and thus eligible to receive VALE grants). As shown in Figure 45, 35 percent of airport respondents are in attainment under the NAAQS, 18 percent are in maintenance zones, and 38 percent are in nonattainment zones (the remainder are Canadian airports, and the NAAQS do not apply).

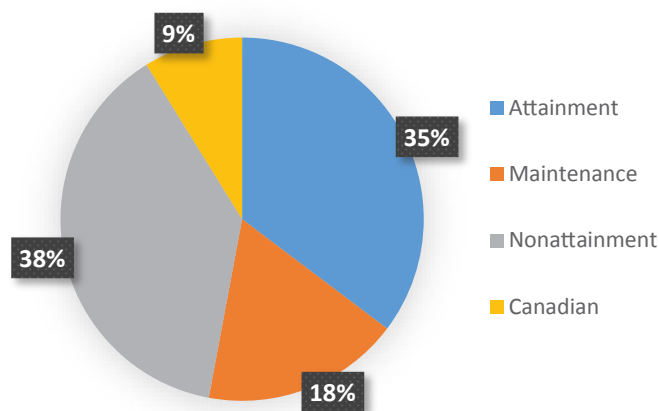


Figure 45. NAAQS status of respondents.

VALE Eligibility

Fifty-six percent of respondent airports are eligible for VALE funding, while 44 percent are not eligible. In order for airports to be eligible for VALE funding, they must be located in nonattainment or maintenance areas for one or more of the six criteria pollutants.

2. Airport Gate Electrification Equipment

The survey contained a number of questions regarding airports' gate electrification equipment, including the number of gates, the number of remote hardstands, the number of gates with electric preconditioned air (PCA) and ground power, mobile units in use, etc.

Gate equipage

A majority of respondents, 68 percent, reported that at least 95 percent of gates at their airport are equipped with *both* electric PCA and ground power. The remaining 32 percent of the respondents reported varying levels of equipage. For example, a few airports reported that all gates are equipped with electric ground power but none with PCA. Other respondents reported having a mix of equipage at gates, some with both PCA and ground power, and some with just ground power. One airport reported no gate electrification equipment in place at all.

Gate ownership

In terms of gate ownership, 85 percent of respondents reported that all gates are airport-owned. The remaining 15 percent reported a combination of both airport and airline-owned gates (see Figure 46).

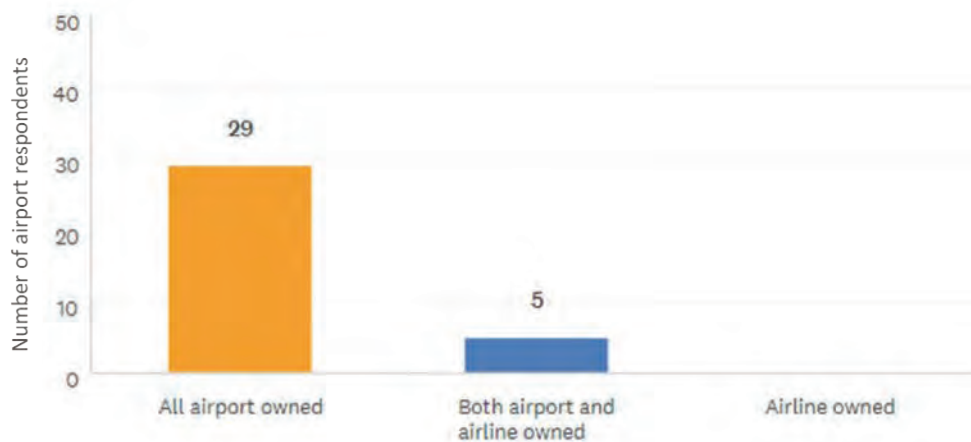


Figure 46. Gate ownership as reported by respondents.

PCA system type

As shown in Figure 47, most respondents have point-of-use PCA systems (24 respondents). Five of the respondent airports have both a central PCA system and point-of-use systems. One airport reported having a central PCA system and no point-of-use PCA equipment.

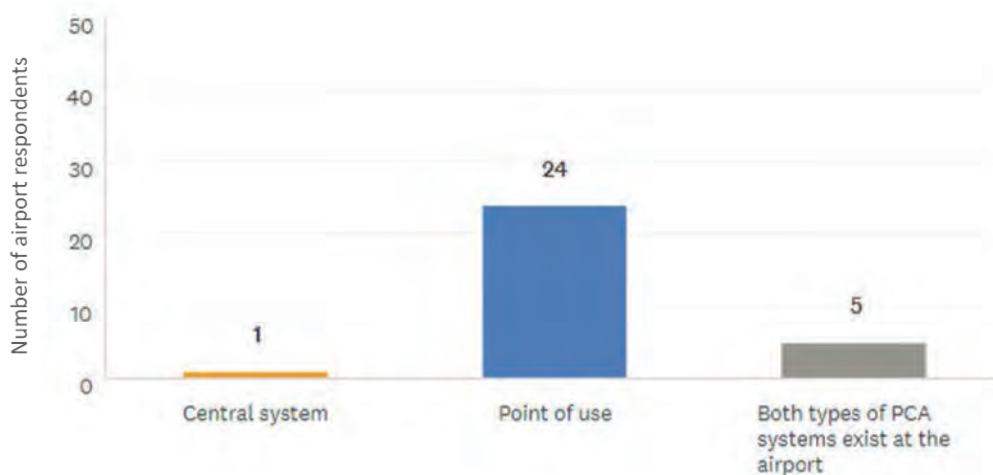


Figure 47. PCA system types as reported by respondents.

Mobile diesel- or propane-powered PCA or GPUs

As shown in Figure 48, of the 25 airports that had data to report on diesel- or propane-powered mobile PCA and GPUs in service at the airport, most had fewer than 10 mobile units, while one airport reported 142 mobile PCA and GPUs.

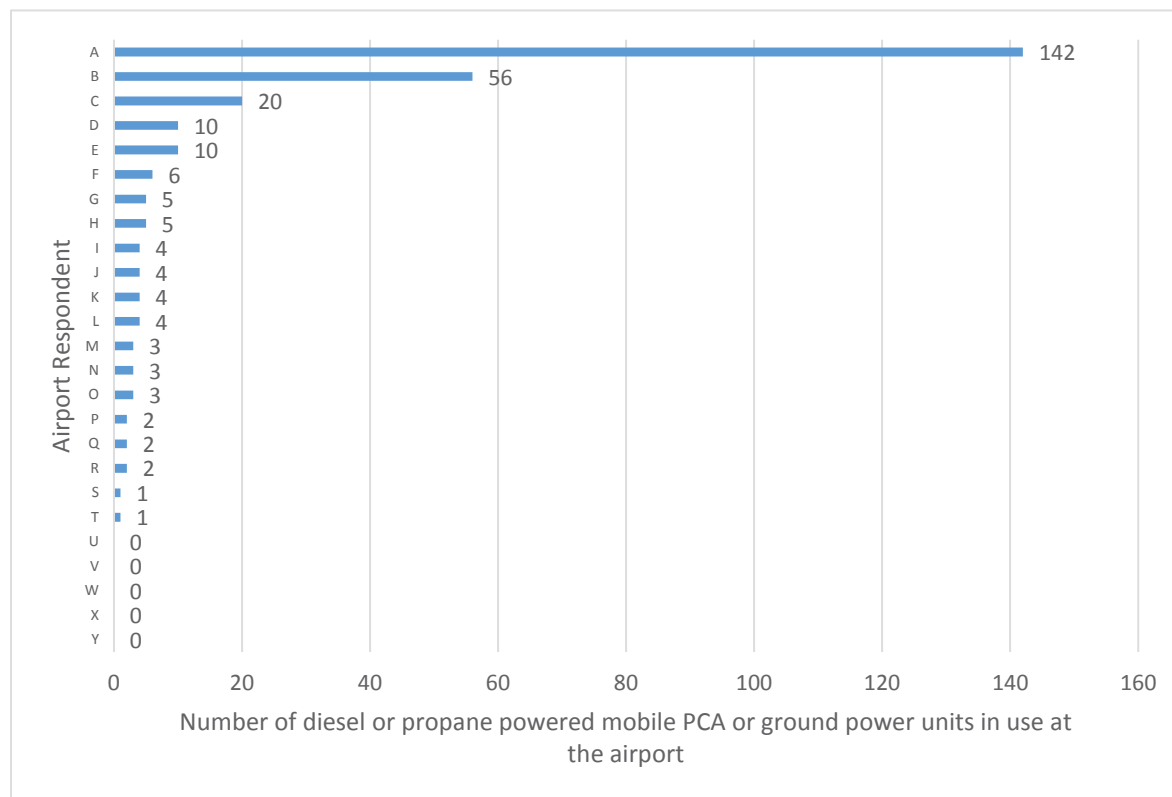


Figure 48. Diesel- or propane-powered mobile PCA or GPU.

Remote hardstand positions at the airport

A majority of respondents (88 percent) have remote “hardstand” positions at the airport.

Use of hardstands

The uses of hardstands vary by respondent, but the majority of respondents do not use hardstands for regular passenger loading and unloading operations. The most common use identified was overnight parking only (45 percent of respondents), shown in Figure 49.

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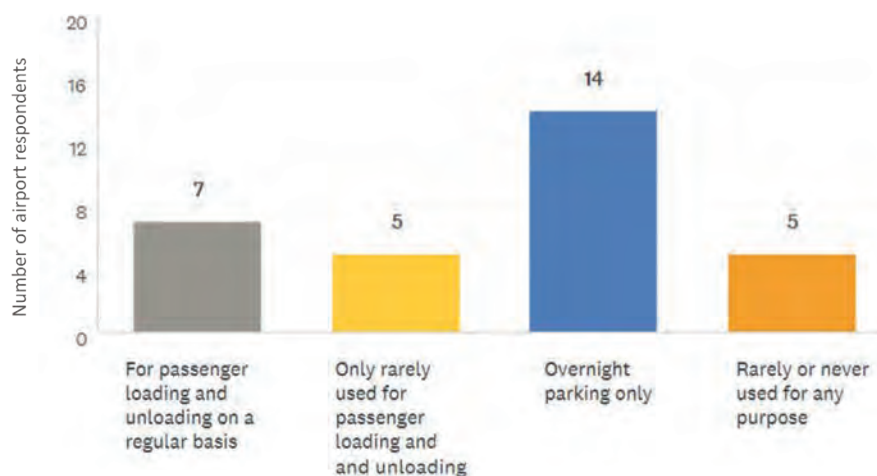


Figure 49. Use of remote hardstand positions as reported by respondents.

3. Utilization Tracking

The survey sought to capture data related to airports' practices and methodology for tracking PCA and ground power system utilization.

Utilization tracking practices

A majority of airport respondents report that they do not track PCA and ground power utilization (68 percent). Close to 18 percent report that they do track utilization and the remainder were not sure (see Figure 50). Of the 6 airports that reported tracking PCA and /or ground power system utilization, all have used VALE grants and are, therefore, required to track hours of use for emissions savings calculations. Of airports that are either ineligible for VALE or are eligible but have not used a VALE grant, none reported tracking utilization.

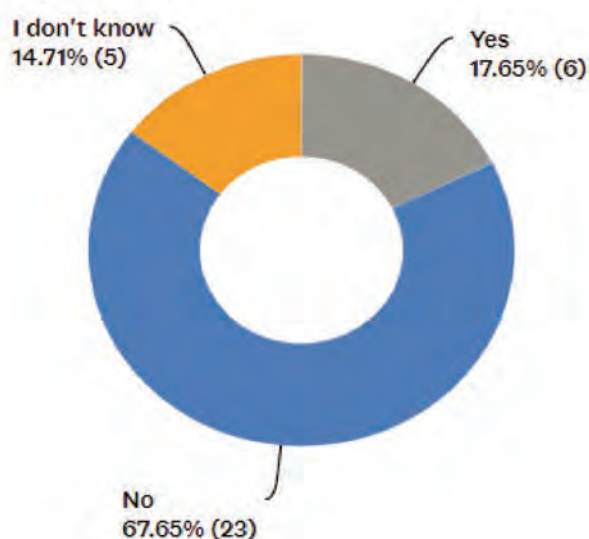


Figure 50. Airports that reported tracking PCA and/or ground power utilization.

Tracking methods

The survey sought to collect information regarding how utilization is tracked. The following responses were received:

- Informal Excel spreadsheet;
- PCA run time hours are tracked quarterly with equipment meters and catalogued in annual reports;
- Periodic readings from equipment meters are taken when needed;
- Hour meters are on the equipment, and the airport has started manually entering the data into their computerized maintenance monitoring system. Hours of use are tracked for equipment acquired with the VALE grant and reported to FAA; and
- Equipment use is monitored with meters (for time in use).

The survey asked airports for the approximate utilization rate of their electric PCA and ground power equipment, and only a few estimates were provided, including:

- 90 percent
- 100 percent
- “Medium to high”

Auxiliary power unit usage

While some airports track PCA and ground power utilization by hours of run time, the research team was interested in whether any airports are also tracking APU use when aircraft are parked at the gate. Only one airport reported tracking APU use by aircraft while parked at gates. When the research team discussed this practice further with the responding airport, it was clarified that the airport does not track *actual* APU use while aircraft are at the gate. The airport looks at the hours of PCA run time and the flight schedules to determine estimated emissions savings from use of PCA as per required by the FAA for VALE grant recipients.

Metering equipment

According to results summarized in Figure 51, most airport respondents do not have individual electrical meters on jet bridges (55 percent), although 39 percent of respondents report that some or all of their bridges are individually metered (while some airports jet bridges are metered, the individual PCA and ground power system components may not be).

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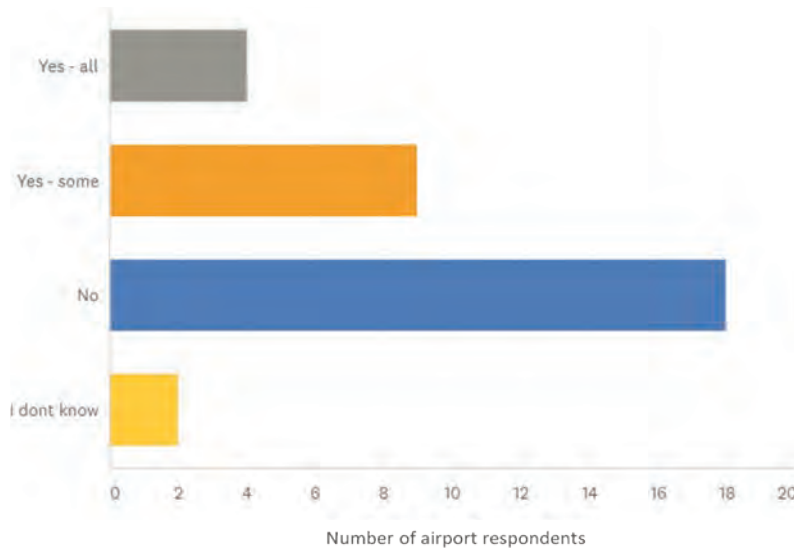


Figure 51. Jet bridge metering.

4. Maintenance of Equipment

The survey sought to collect information on maintenance of PCA systems and ground power equipment. This includes the parties responsible for maintenance, as well as communication and coordination methods between stakeholders.

Maintenance of electric PCA and ground power equipment

Approximately half of respondents (51 percent) reported that either airport staff or airport-provided third-party service providers maintain the electric PCA and ground power systems. Only 4 respondents reported that these systems are maintained by airline staff or airline-provided contractors (approximately 11 percent). The remaining respondents reported that a combination of these parties are responsible for maintenance as shown in Figure 52.

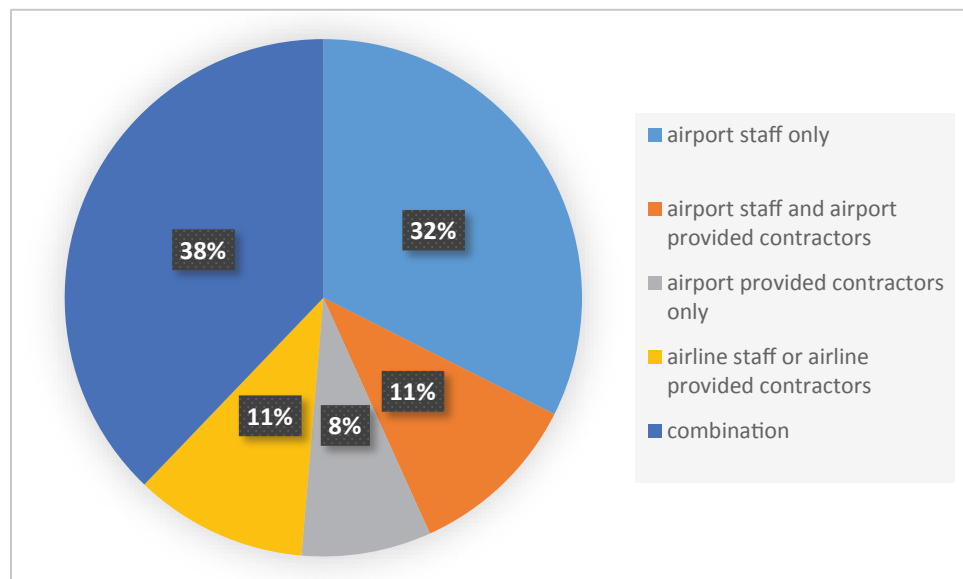


Figure 52. Maintenance of electric PCA and ground power equipment.

5. Communication Protocols

Participants in the focus groups and case study interviews noted the importance of communication between the airport, airlines, and maintenance and ground crews regarding the availability and status of the gate electrification equipment. The survey included two questions on communication about electric PCA and ground power equipment status: 1. how airlines notify airports of damaged or inoperable equipment, and 2. how airports notify airlines when equipment has been repaired and is back in service. Both of these questions were open-ended (i.e. no pre-set answers).

Notification when equipment is out of service

Sixty-four percent of respondents reported that ground handlers or airline staff contact airport operations or maintenance departments directly when there is a problem with the PCA or ground power equipment. An additional 18 percent replied that airlines notify the airport via a designated telephone number or hotline, but did not specify if the number was to operations, maintenance or other airport department. The remaining 18 percent replied that the question did not apply or that they were unsure of the communication protocols.

Notification when equipment is back in service

Once the electric PCA and ground power equipment has been restored to service, the parties responsible for maintaining the equipment notify the airlines. A range of answers for how this communication takes place was provided, but in general, 46 percent of airports reported using email and/or phone notifications, 27 percent reported some sort of direct verbal communication with airline staff, and 15 percent reported using some form of automatic notification. The remaining responses varied, including equipment status indicated on each gate, or the question was not applicable (i.e., if the airport does not maintain the equipment).

General communication protocols

The survey included an open-ended question about communication practices between the airport and airlines (not limited to the status of PCA and ground power equipment). Some airports provided multiple methods of communication. Aggregated method types are included in Figure 53. Based on responses, the most common forms of communication are in-person, phone, and email.

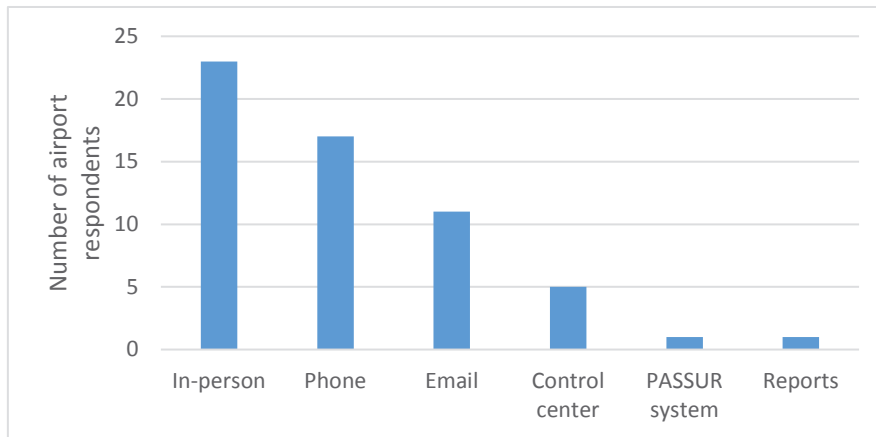


Figure 53. Communication methods utilized for airport and airline coordination.

6. System procurement and policy

The survey collected information concerning procurement of PCA and ground power systems, as well as policies in place to govern their use.

Primary drivers for equipment acquisition

Airport respondents were given a range of possible motivating factors for acquiring and installing gate electrification equipment (and were able to select multiple responses). The two most common primary drivers that airports reported affecting their decision to acquire and install this equipment are: 1. provide the service to airlines, and 2. airport leadership commitment. Results are depicted in Figure 54.

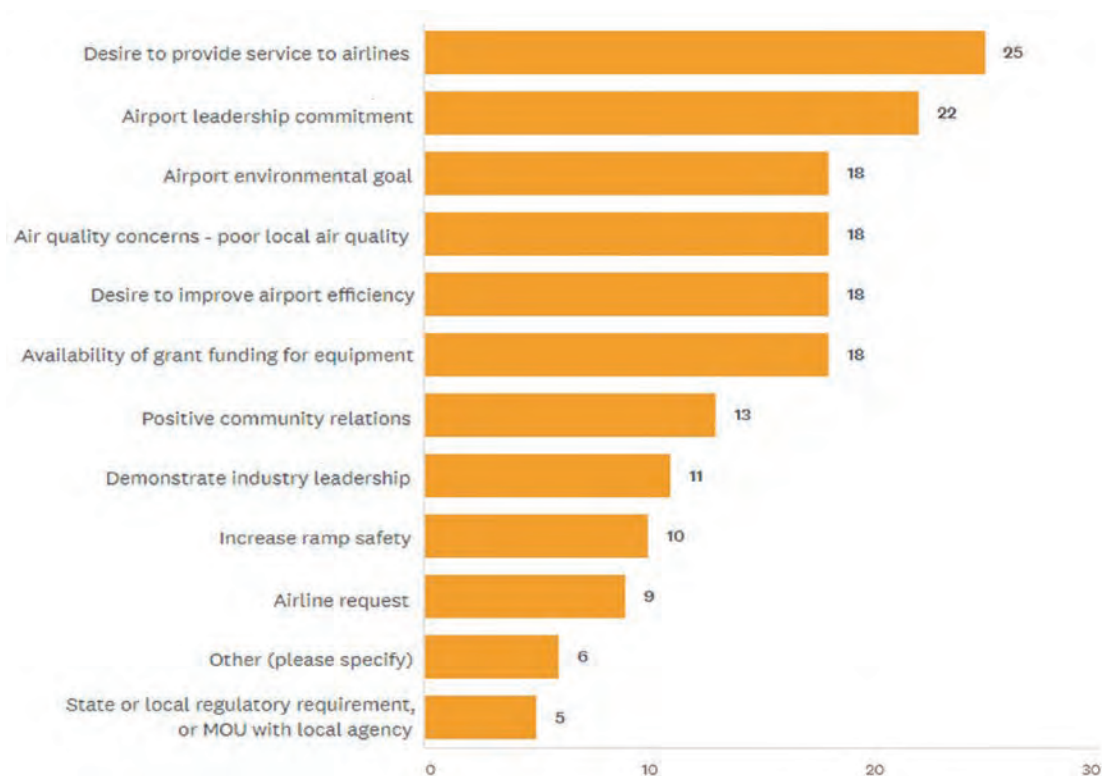


Figure 54. Primary drivers for PCA/ ground power installation.

Financing the acquisition, maintenance, and operation of equipment

Several mechanisms are employed by airports to finance the installation, operation, and maintenance of their electric PCA and ground power systems. Respondents were able to check all that applied to their airport. Based on responses, the most common funding comes from capital improvement programs, operating budgets, and VALE grants. Some examples of “other” items listed by airport respondents include Passenger Facility Charge (PFC) funds, Airport Improvement Program (AIP) funds, and terminal construction/ re-construction projects (see Figure 55).

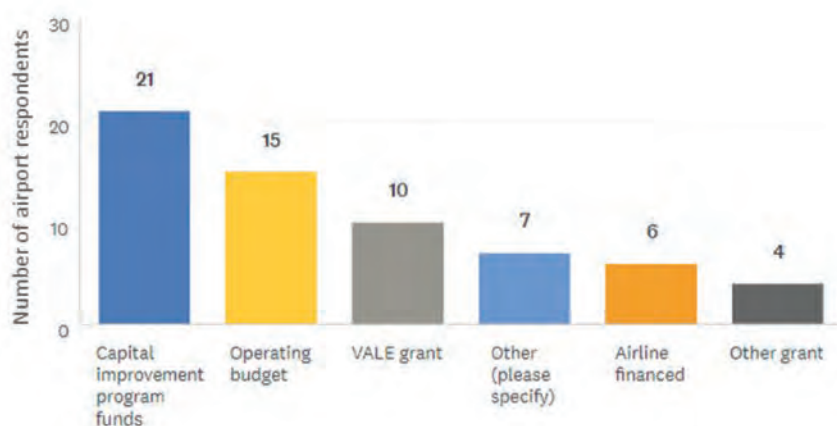


Figure 55. Mechanisms used to finance PCA/ ground power systems.

Electricity costs

Airports were asked how they charge airlines for the electricity costs associated with electric PCA and ground power utilization. According to survey results, a majority of airport respondents charge airlines for electricity use through incorporation in lease rates and charges, as opposed to charging airlines for actual electricity use (which would require individual electrical meters on gates and equipment, and mechanisms for tracking use on shared gates). This was an open-ended question, and responses were categorized into the general categories listed in Figure 56. The intent of the research team in including this question on the survey was to determine if there is a link between how airlines are charged for electricity and utilization tracking practices and utilization rates. The lack of electrical meters on equipment at most airports results in those airports being unable to determine PCA and ground power use by electricity consumption. In addition, the general lack of utilization tracking prevents the establishment of a relationship between how airlines are charged for electricity and utilization rates.

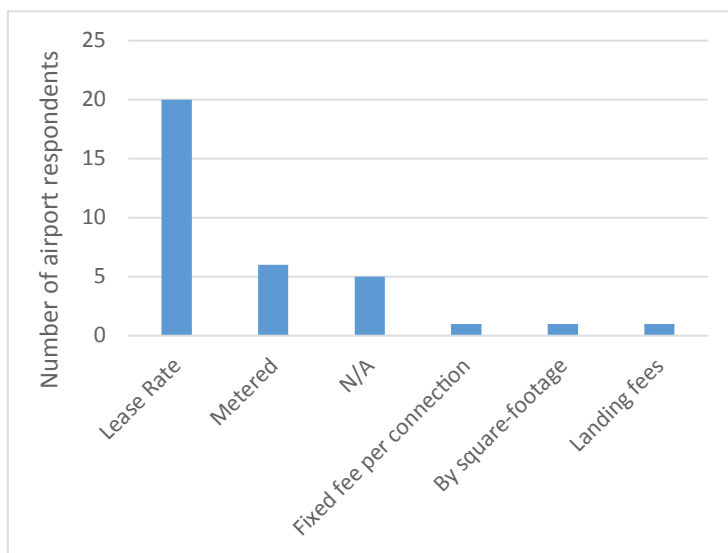


Figure 56. Methods for charging airlines for electricity.

Cost-benefit analysis for gate electrification systems

The survey asked respondents if they conducted a cost-benefit analysis (CBA) for the acquisition and installation of electric PCA and ground power. About half of respondent airports (51 percent) reported that they did not conduct a CBA, 18 percent did perform some sort of CBA, and the remainder did not know whether a CBA had been performed. Although the application process for FAA VALE grants requires the airport applicant to estimate the cost per ton of pollutant reduced through the project, a number of airports that received VALE grants for PCA/ground power equipment reported that they did not conduct a CBA or did not know if a CBA had been conducted. This inconsistency may be attributed to unclear wording on the survey instrument (i.e., airports were not specifically instructed that estimates prepared for VALE applications could be considered a CBA). Further, VALE grant applications do not consider GHGs as part of the emission reductions estimates.

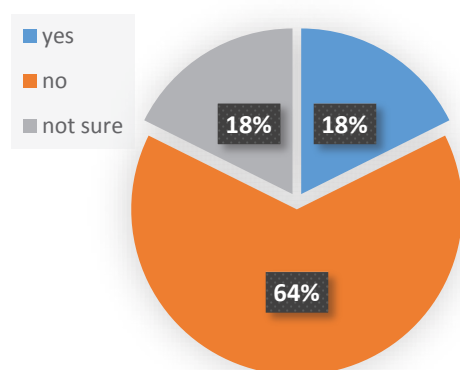


Figure 57. Airports with policies or incentives for airline PCA and ground power use.

Policies regarding PCA and ground power use

Airport respondents were asked if they have any policies, incentives or regulations to encourage airline use of electric PCA and ground power equipment (Figure 57). The majority of respondents (64 percent) do not have any policies or incentives in place regarding the use of electric PCA and ground power by aircraft. There were 6 airports (18 percent) that reported some type of policy or incentive in place, and 6 airports that reported they were unsure if the airport had a policy in place. Of the 6 airports with policies encouraging the use of electric PCA and ground power, 4 have used VALE grants to acquire at least some of their PCA and ground power equipment.

One example of an airport policy that encourages use of PCA and ground power is from Philadelphia International Airport. Their Rules and Regulations Manual states in Section 3, Aircraft Operations, “Operators should use ground power and pre-conditioned air when available and practicable” (pages 3–9). Another example is from San Diego County Regional Airport Authority, which has a Memorandum of Understanding with the Attorney General of California requiring San Diego International Airport to equip gates with electric PCA and ground power, and to coordinate with the airlines on the design and provision of the equipment (SDCRAA MOU, 2008).

7. Challenges and barriers to utilization

The survey asked airports to identify the main challenges to utilization of electric PCA and ground power, and provided both a selection of pre-set answers and an open-ended response option. Over half of airport respondents identified ground crew equipment misuse and kinked PCA hoses as challenges or barriers to utilization. Although kinked hoses can be caused by incorrect deployment or storage of the PCA hose (which could result from incorrect equipment use), this challenge in particular was cited frequently enough by focus group and case study participants that the research team included this as a separate answer choice (see Figure 58).

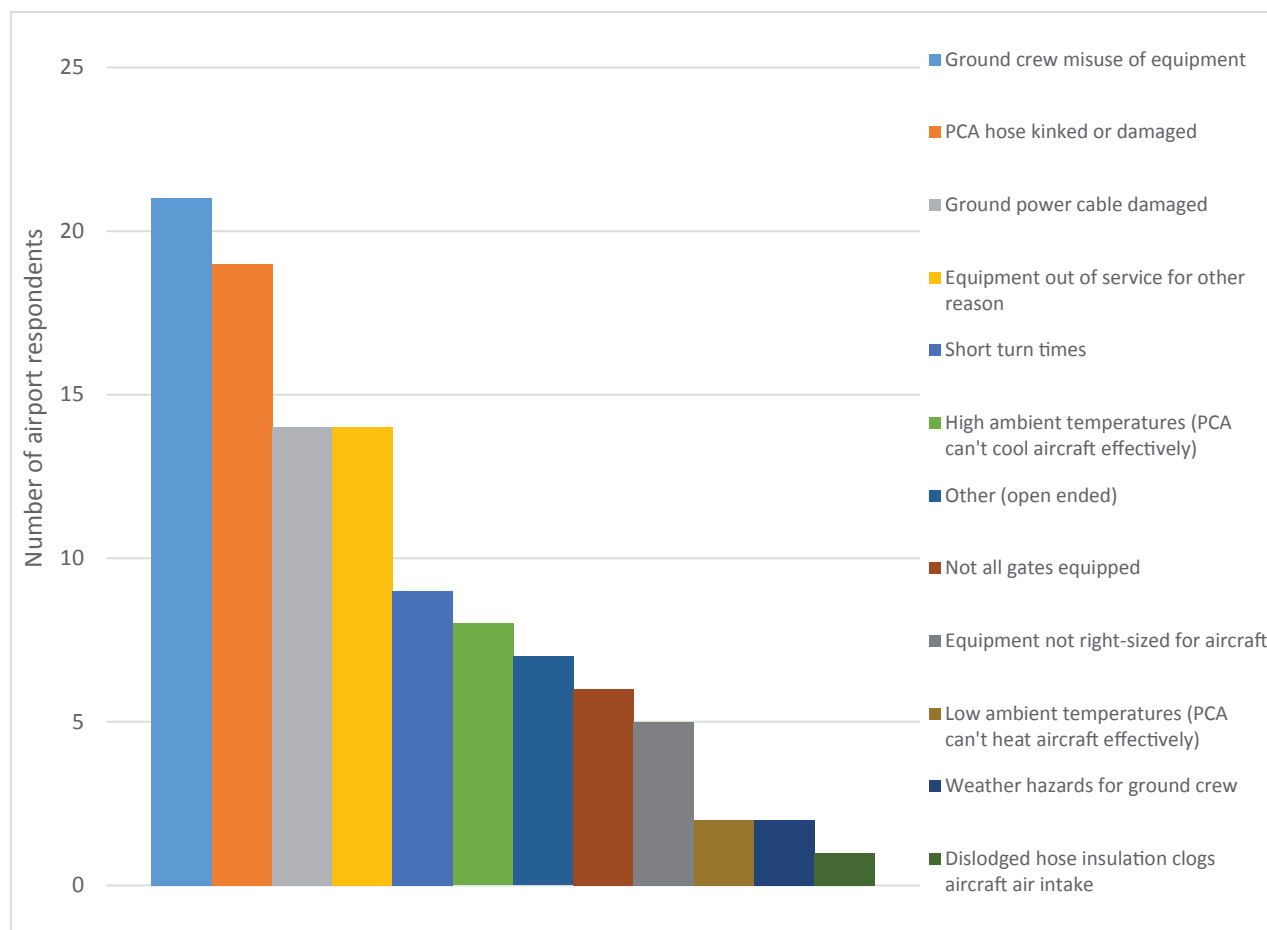


Figure 58. Challenges to PCA and ground power utilization.

8. Survey conclusions

While the survey results cannot be interpreted to represent all airports in the U.S., the 34 airport respondents do represent a range of airport sizes, geographic locations, climate zones, and local air quality status. The results of the survey combined with the focus group and case study interviews provided the research team with an understanding of the different types of electric PCA and ground power configurations, ownership and maintenance structures, drivers for installation, utilization tracking methodologies in place, and common challenges to electric PCA and ground power use. Some of the conclusions drawn from the survey results include:

- The primary driver why airports install gate electrification equipment is to provide the service to airlines. This fact suggests airports recognize it is not cost-effective for airlines to provide gate power and conditioning through APUs and diesel power GPUs.
- Airports are funding installation of this equipment with their own financial resources more often than relying on matching funds.
- Airports located in non-attainment zones are using VALE funds. However, about half of respondents are in non-attainment zones, indicating that just as many airports that are not eligible for VALE are implementing gate electrification measures. These data support responses that the primary driver is not regulatory or environmental, but service to the airlines.

- Few airports track equipment utilization. This makes it difficult to ascertain level of equipment use and opportunities for optimization.
- The cost of operations and maintenance is not tracked. Investing in tracking equipment could result in cost savings to the airport.
- The primary barrier to use is non-functioning equipment, and kinked hoses have been a specific issue.
- Airports and airlines have established direct lines of communication to address gate electrification equipment operational issues.

Airports that have received VALE grants are required to track use of equipment purchased with the grant funds for the purposes of calculating emissions savings. However, beyond those airports tracking hours of use for VALE purposes, airports are generally not tracking utilization in any kind of formal, systematic manner. Several airports interviewed for the case studies and in this survey reported anecdotally that utilization rates are high, but there was no precision provided. The data do not support conclusions correlating individual airport characteristics and practices with specific increases or decreases in electric PCA and ground power utilization. However, the survey data do support the findings from the focus groups and case study interviews regarding the identification of common challenges, and general solutions.



APPENDIX C

Pilot Survey Summary

The research team sought the input of commercial airline pilots via an online survey on impediments to the use of electric preconditioned air (PCA) units and electric ground power systems (collectively referred to as gate electrification systems), and potential opportunities to overcome these challenges. As pilots have ultimate control over the aircraft and the decision concerning whether or not to use APUs, their perspective is critical to understanding utilization of gate electrification systems.

The survey questions were developed based on initial focus group and case study stakeholder input. They were also reviewed and approved by the project panel. They included questions covering pilots' APU use, communication related to APU use, experience concerning the reliability of gate electrification equipment, opinion on improving gate electrification utilization, and knowledge of related airline policies. The survey was distributed electronically via Survey Monkey (online survey software) to individual airline representatives identified during the project and to the Air Line Pilots Association (ALPA). It was also announced by research team members via social media through LinkedIn.

1. Respondent Summary Data

The research team received 232 total responses to the survey. This section covers demographic characteristics of the pilot survey respondents.

Pilot airline affiliation

Respondent pilots represent a variety of airlines including American Airlines, British Airways, Delta Air Lines, United Airlines, and Southwest Airlines. Although the survey was widely distributed, a significant majority (83 percent) of the responses came from just one airline. Significant efforts were made by the research team to solicit additional responses from a variety of airlines, including follow-up emails and outreach to ALPA, airline representatives that participated in case study interviews and individual survey respondents to encourage participation from their peers. These efforts resulted in some additional responses but the overall distribution of survey responses remained unbalanced in favor of the one airline with the greatest number of pilot respondents. For this reason, some of the survey responses summarized in this section were analyzed and disaggregated to show responses broken out – one set of responses from the majority respondent airline's pilots (referred to "Airline 1 Pilot Respondents"), and the second set of responses from all other airlines ("All Other Respondents"). In general however, the responses of Airline 1 Pilots and the other respondents were comparable.

Types of aircraft flown

The survey collected information concerning the general type of aircraft that pilots typically fly. Pilots were able to select multiple response choices. A majority of pilot respondents fly narrow-body aircraft. This was consistent for both Airline 1 Respondents as well as all other respondents (see *Figure 59*).

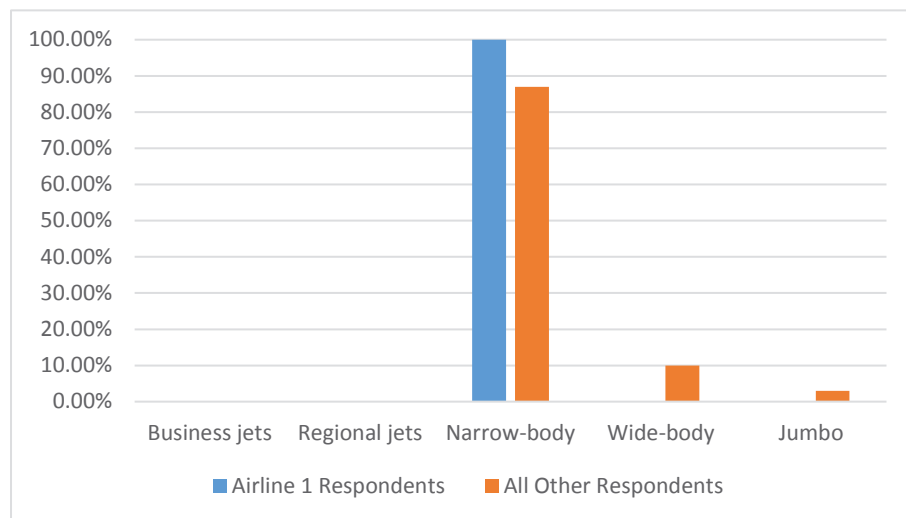


Figure 59. Types of aircraft flown by pilot respondents.

2. Survey Responses Summary Data

The survey collected data from pilots on a variety of measures to identify challenges to utilization and best practices to improve utilization of gate electrification systems.

APU Use

The survey collected information concerning the conditions in which pilots choose to run the aircraft APU even if electric PCA and/or ground power is available. The four most common responses were: 1. ambient temperatures are too hot for PCA to effectively cool the aircraft; 2. equipment is out of service; 3. ground crew does not connect aircraft; and 4. weather conditions are unsafe for ground crew to connect the aircraft. The responses are summarized in Figure 60, depicting Airline 1 Pilot Respondents in blue and all other respondents in orange.

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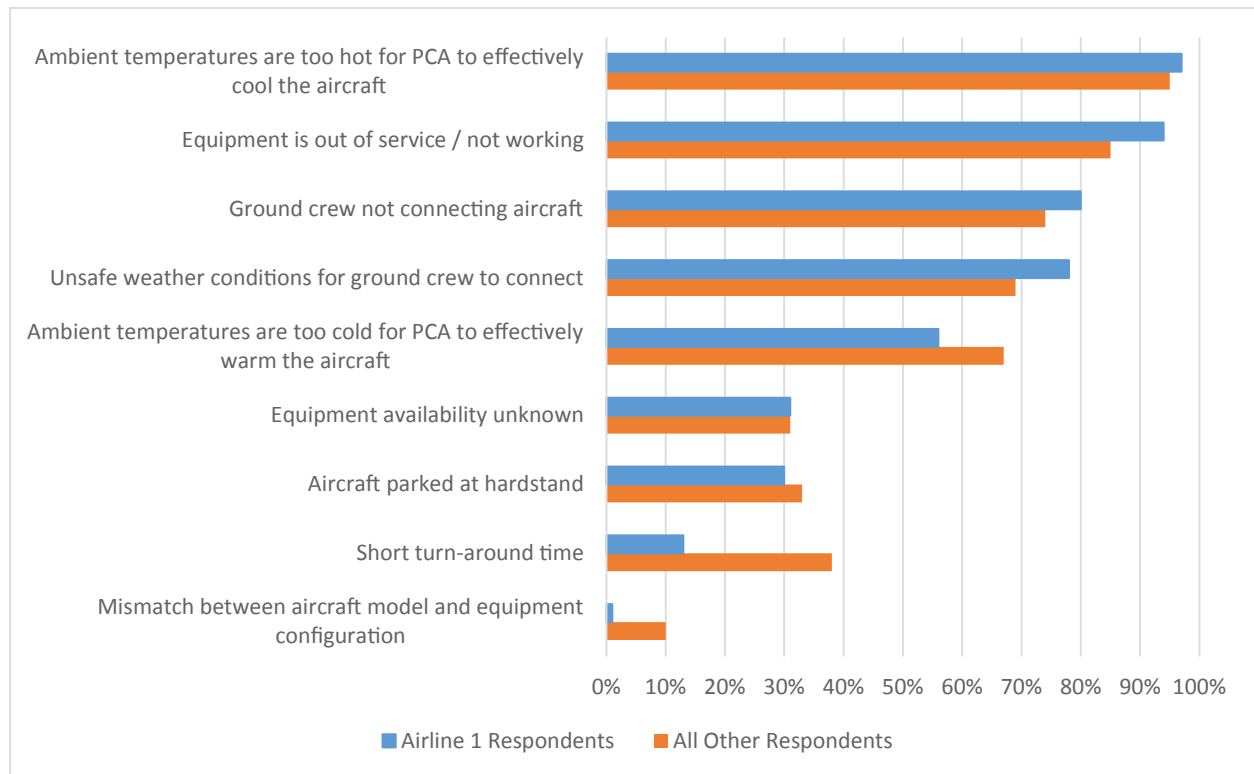


Figure 60. Reasons pilots turned on their aircraft's APU while parked.

Respondents were also able to enter in additional reasons not listed in the survey for using the APU when electric PCA and ground power are available. Below are summaries of some responses:

- Consistently poor quality (of gate electrification equipment) creates general lack of confidence in the equipment;
- Preprogrammed PCA systems to change from warm to cold seasonally can result in the aircraft running APUs for several months of the year during shoulder seasons (fall and spring) because of unpredictable and variable ambient temperatures;
- Certain aircraft models seem to have ducting issues that prevent PCA from reaching the cabin;
- If only one of the systems (PCA or ground power) is available and not the other, the APU will be turned on;
- Lack of temperature gauge or sensor for regulating temperature of PCA. Sometimes the air is too cold or too hot (as opposed to not cool or warm enough).

Communication concerning APU use and fuel burn

Several airline representatives stated during the focus group and case study interviews that their companies track APU fuel use, and in some cases communicate with airline station managers if fuel use is higher than anticipated. APU fuel use data can be used to determine if aircraft are using their APUs more than anticipated, which could signify that electric PCA or ground power was not available. The survey asked the pilot respondents if they receive communications directly from their airline if an anomaly in APU use or fuel burn is detected.

Responses to this question were analyzed based on Airline 1 Respondents and all other respondents. A majority of Airline 1 Respondents (60 percent) report that their airline does *not* communicate with them directly concerning this item (negative responses shown in orange on both charts in Figure 61).

Conversely, a majority of all other airline pilot respondents (57 percent) report that their airline *does* communicate directly with them if an APU fuel use anomaly is detected (positive responses shown in blue in Figure 61). The number of respondents who replied “I don’t know” was similar for Airline 1 Respondents and all other airline respondents (12 and 15 percent respectively).

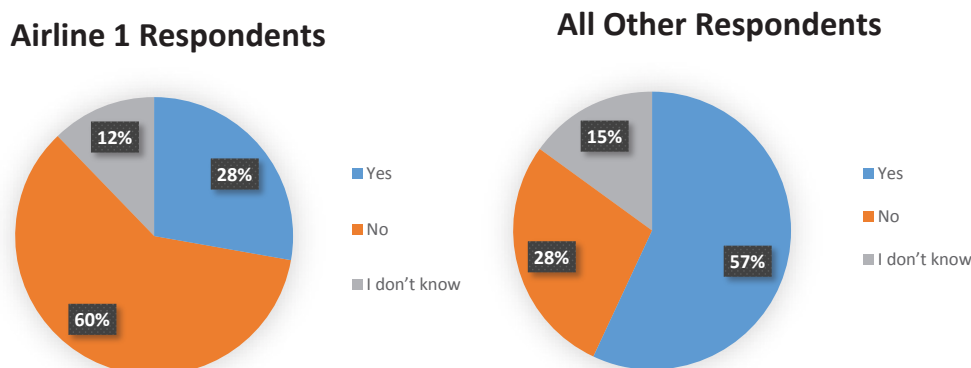


Figure 61. Comparison of responses concerning communication of anomaly in APU use/fuel burn. The survey question asked: Does your airline communicate with pilots when they detect an anomaly in APU use/fuel burn?

Reliability of gate electrification equipment

Both the airport and the pilot surveys demonstrate that electric PCA and ground power equipment reliability is not uniform across all airports. A majority (57 percent) of all pilot respondents report that there are airports at which the PCA and ground power equipment are more readily available and reliable than at other airports. In addition, a majority (68 percent) of pilot respondents report that there are airports where they have experienced consistent problems with the availability and reliability of this equipment. If pilots experience consistent problems with electric PCA and ground power equipment at a particular airport, they may lose confidence in the reliability of the equipment, and by default turn on the APU.

Improvement of gate electrification utilization

The survey asked respondents for their opinions on actions and practices that could improve utilization of electric PCA and ground power systems (listed in Figure 62). Respondents to this question were able to check all that applied in their opinion. Although the answers were similar for both Airline 1 Respondents and all other respondents, the selections are shown separately in Figure 62.

A majority of all responding pilots agree that increasing the availability and reliability of electric PCA/ground power equipment is the most critical action to improve utilization [airline personnel explained to the research team through case study interviews that pilots consider PCA and ground power equipment to be unavailable when it is damaged, out of service, *and* when it is not “right sized”, (i.e., not sufficiently powerful to meet the aircraft’s needs)]. Another common opinion expressed in the survey is support for

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a PCA system that pulls air from terminals instead of the apron, so that air being pulled into the PCA is already better conditioned.

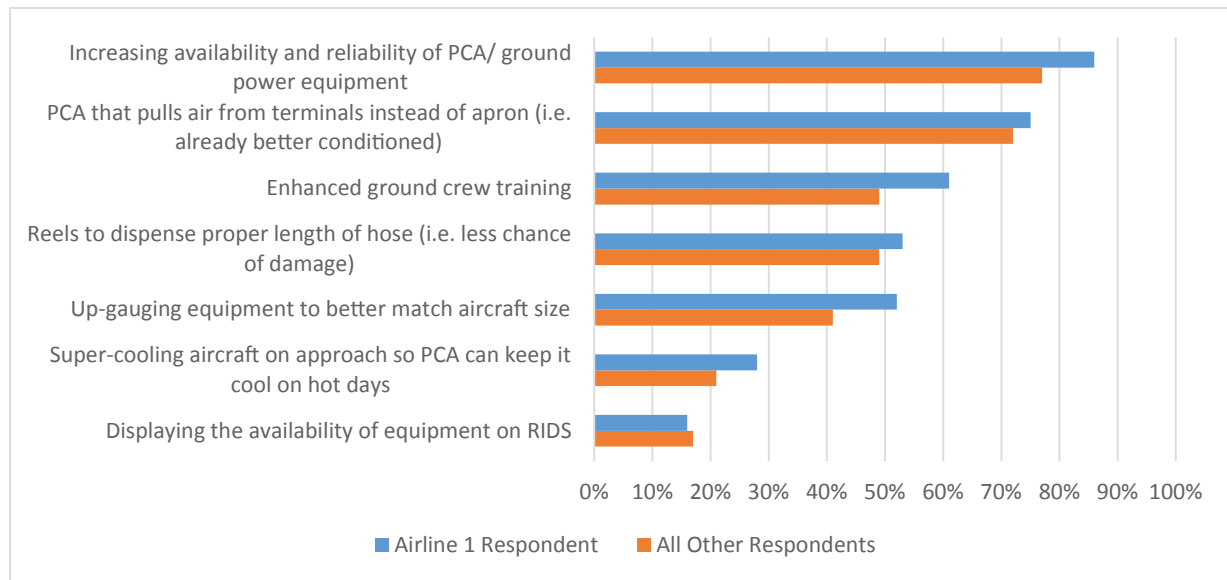


Figure 62. Opinions on how to improve utilization of PCA/ ground power (RIDS stands for Ramp Information Display System).

Respondents were also able to enter in additional suggestions for improving utilization of this equipment. Fifty-four respondents replied with potential solutions, which are summarized below (similar responses were consolidated):

- Ensuring proper length of PCA hoses is dispensed, removing hose kinks, checking for holes in the hoses;
- Addition of better temperature sensors and controls to match ambient air temperature (some also suggested providing pilots with control over PCA temperature);
- Adequately sized equipment (i.e. more powerful PCA units);
- Proper maintenance of equipment to improve reliability;
- Improved communication between ground crew and flight crew before disconnecting PCA;
- Improved training for ground and flight crews;
- Insulated PCA hoses to minimize loss of cooled/heated air over the length of the hose;
- Closing aircraft window shades, opening air vents;
- Hoods on provisioning trucks to prevent loss of cooled/heated air from aircraft cabin when aircraft doors are open.

Airline policies

A majority of pilot respondents report that their airline has specific policies or requirements in place regarding the use of gate electrification equipment when available, and for communication of problems or issues with the equipment.

Although the responses were similar, Airline 1 Respondents (blue color in Figure 63) are broken out from all other respondents (orange color). Approximately 77 percent of Airline 1 Respondents report that they are aware of their airline's policy regarding communication and coordination between pilots and ground crews for the use of electric PCA and ground power, while 67 percent of other respondents report that they are aware of this type of communication protocol. This represents a possible area of focus for airlines, to communicate these policies with pilots to reduce the number who are currently unaware of such policies and procedures.

The survey also asked the pilots if their airline has a reporting process for pilots to notify the airline headquarters when gate electrification systems are inoperable at an airport. About 85 percent of Airline 1 Respondents answered that their airline does have this type of policy, whereas 79 percent of all other responding pilots reported this type of process.

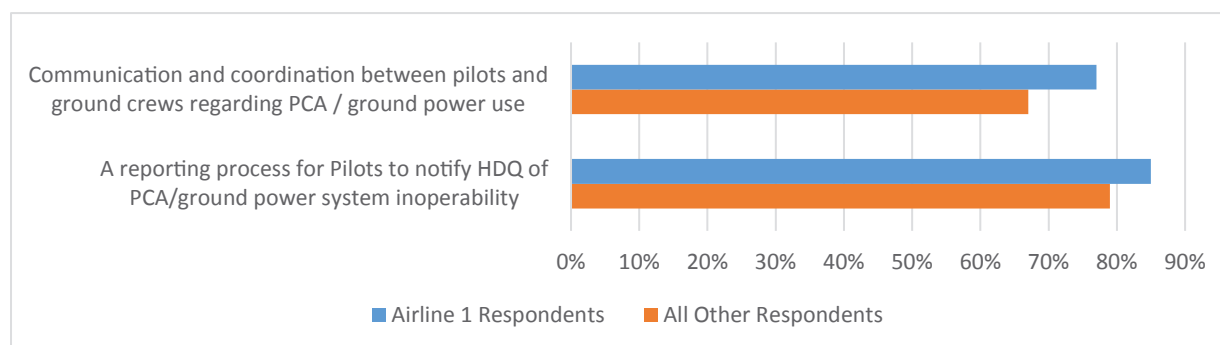


Figure 63. Pilot awareness of airline policies or requirements regarding PCA/ ground power communication issues.

3. Survey Conclusions

The survey results provide a snapshot from a relatively small percentage of pilots. However, the 232 pilot responses combined with the focus group and case study interviews which included airline representatives in most cases provide the research team with an understanding of operational issues faced by pilots when considering the use of gate electrification equipment. Some of the conclusions drawn from the survey results are listed below.

- In general, the responses were similar across all airlines represented despite the imbalance in responses.
- The most important barrier reported by pilots to the use of gate electrification equipment is availability and reliability.
- Pilots' decisions to use APU instead of gate electrification equipment may vary from airport to airport, and where gate electrification reliability issues are common, pilots are less likely to initiate use of the equipment (i.e., they are more likely to use APUs without trying to connect to gate electrification equipment first).

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- Many pilots provided additional comments in the open text sections of the survey which indicated a lack of confidence in the effectiveness of PCA systems to condition aircraft cabins (even when the equipment is operational), due to too high ambient temperatures, lack of temperature control mechanisms to adjust air coming out of the PCA hose, and compromised equipment such as kinks or tears in the PCA hose.
- Pilot responses about awareness of airline policies regarding use of gate electrification equipment, communication with ground crew, and reporting problems suggests an opportunity for improvement that can affect overall utilization.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAAE	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
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRRP	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
TDC	Transit Development Corporation
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

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