STRATEGIC **INSIGHTS**

Solar, Wind Power at Dulles Airport

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STRATEGIC RESULTS

OVERVIEW

This paper will examine the efficacy of utilizing solar and/or wind power as an energy source for Washington Dulles International Airport (IAD). We provide tools to estimate the financial costs and energy return on investment (EROI) of using solar and wind power, and discuss methods and strategies to implement these renewable energy sources. Finally, we observe case studies of similar transitions to renewable energy.

SOLAR ENERGY (Source: *Technical Guidance for Evaluating Selected Solar Technologies on Airports*)

Introduction:

Though solar energy has been evolving since the early 1990s as a mainstream form of renewable energy generation, the expansion in the industry over the past 10 years and corresponding decrease in prices has only recently made it a practical consideration for airports. Solar technology has matured, and now presents itself as an opportunity for FAA and airports to produce on-site electricity and to reduce airport operating costs. Solar energy is particularly well-suited to airports because of the available space at airports, unobstructed terrain, and energy demand. Environmentally, solar energy shows a commitment to environmental stewardship, especially when the panels are visible to the traveling public. Among the environmental benefits are cleaner air and fewer greenhouse gases that contribute to climate change. Solar use also facilitates small business development and U.S. energy independence. While solar energy has many benefits, it does introduce some new and unforeseen issues, like possible glare (reflectivity) and communication systems interference, which have complicated FAA review and approval of this technology. The guidance compiled by FAA discusses these issues, highlights case studies, and discusses solar financing.

Solar PV Basics:

A solar PV system is made up of multiple components that collect the sun’s radiated energy, convert it to electricity and transmit the electricity in a usable form. The main component is the solar panel, which is typically comprised of 40 individual solar cells that convert sunlight energy to electricity. The electricity produced by individual panels is direct current (DC) which is brought together in a combiner box and fed as a single DC flow to an inverter. The inverter converts the electiricty produced by the PV cells from DC to alternating current (AC), a form that can be tapped by users of the electrical grid.

Types of Solar PV Technologies

The primary types of PV technologies applicable to airports are those associated with **crystalline silicon panels**. Solar cells assembled in panels are made of silicon and are the most efficient technology for converting light energy to electricity. Monocrystalline panels are made of large silicon crystals which are less common and therefore more expensive but also operate more efficiently. Polycrystalline panels are made of many small silicon crystals and are the most common type of solar panel. Other types of PV technologies include **thin film** and **multi-junction** versions.

Thin-film solar is made from amorphous silicon or other materials such as cadmium telluride. While less efficient than traditional solar cells, thin-film can be deployed less expensively on flat building surfaces such as building rooftops and facades to generate electricity. Multi-junction systems consist of multiple thin-film layers that increase efficiency.

Energy Conversion Process and Efficiency

Solar electricity performance is affected by geographic, meteorological, and technical conditions. Electricity production is dependent on the amount of solar irradiance at any one location, cloud cover, and other environmental factors such as smog and dust. The amount of energy available also changes daily and seasonally depending on the position of the sun in the sky. Information of solar irradiance for specific U.S. locations can be found on the NREL website.

Panel capacity is the amount of electricity that can be generated by the panel at maximum output. The capacity is determined by standardized testing in laboratory conditions. The panel capacity proposed for any new system will be determined based on factors including available space and project budget.

Power production from a solar panel is calculated based on (1) the panel's rated power, (2) the solar energy availability (monthly average), and (3) efficiency loss due to elevated operating temperatures.

[watts] x [hours] x [%] = kWh

Other Solar Power Generating Systems

Though often less suitable to airports, other types of solar power generating systems exist, and may be useful.

1. **Concentrated Solar Power (CSP):** The most common means for producing electricity in these systems is to heat water and produce steam, which drives a turbine. The two most common CSP designs are parabolic troughs and power towers. One of the benefits of either form of CSP over PV is that the heated fluids can be used to store energy and deliver electricity even when the sun is not shining. *CSP projects require enhanced coordination with the FAA due to unique issues with reflectivity, thermal plumes, radar interference, and airspace penetration.* CSP is typically not compatible with airports.
2. **Solar Thermal Hot Water:** Solar thermal refers to conventional systems used to produce hot water by exposing water to the sun's energy either directly or by heating a fluid in a closed loop that heats the water. Their greatest benefit to areas already served by the electric grid is to minimize the electricity demand on domestic or commercial water heaters to keep water constantly hot. Solar thermal has been best demonstrated as a supplementary source for domestic uses based on frequency of hot water use and level of demand. Airports may want to explore the opportunity of conventional solar thermal hot water at the same time they are looking at solar PV depending on specific hot water use conditions at the airport.
3. **Transpired Solar Collectors:** Also called "solar walls," transpired solar collectors are placed on the sides of building to pre-heat ventilation air inside the building. This system is particularly good for building activities that require constant ventilation and are effective in sunny climates with long heating seasons.

Compatibility

Solar PV tends to be the technology that provides the best opportunity for airports today. Based on the available information, solar PV for an airport application has the best cost-benefit ratio of the solar power alternatives. Solar PV is more compatible with airport land use because it:

1. Is most cost-effective when serving a smaller on-site electricity demand as opposed to large-scale generation for the electricity grid;
2. Has a low profile and modular design, which is compatible with low-demand airport property such as rooftops and airfields;
3. Is designed to absorb sunlight (rather than reflect it), minimizing potential impacts of glare;
4. Does not attract wildlife, which is a critical aviation hazard.

Photovoltaic Designs for Airports

1. Roof-mountings
    a. Optimal location for solar panels because of unobstructed sun exposure
    b. Roofs provide a ready-made support structure for solar installation (no need for costly engineering)
    c. South facing angled roofs require less support structure than flat roofs or those facing other directions
    d. Special mountings need to be considered in areas prone to hurricanes and other seasonal weather events
2. Ground mountings
    a. Requires flat or gently rolling terrain with unobstructed views to the south
    b. Require geotechnical analysis to confirm long-term stability of soils that support them
    c. While panel-for-panel costs may be higher, economies of scale can make larger systems more economical when space is not a limiting financial consideration.
3. Tracking
    a. Tracking systems employ hydraulic or motor-driven mechanisms to move the panels so that they are continuously perpendicular to the sun, maximizing electric generation potential.
    b. Panels can move in two directions (vertical and horizontal). If the system employs one of these tracking systems, it is a “single-axis” system. If it employs both, it uses “dual-axis” tracking.
    c. In snow or dusty conditions, maintenance issues are greater, and financial returns decrease.
4. Remote Systems
    a. The advantage of solar for remote systems such as highway signs, monitoring devices, or obstruction lights is that they do not require connection to the grid.
    b. The disadvantage is that even with a back-up battery, there is a potential risk that power can become interrupted.
    c. Airports with solar-powered LED obstruction lights include Chicago O’Hare, Los Angeles International, and False River Louisiana.

Potential Impacts of Solar Energy Technologies

- **Physical Penetration of Navigable Airspace** as defined by FAR (Federal Aviation Regulations) Part 77—Structures rising more than 200 ft above ground level or less when located close to airports intrude on defined airspace.
    - Solar energy facilities, including PV and CSP, can penetrate airspace. However, because PV utilizes low profile equipment, it is less likely to affect airspace unless it is located very close to an airport runway.
    - Steam boilers are located high up on power towers.
    - Concentrating solar power projects that heat steam to drive a turbine require cooling systems to cool water for reuse. Those that employ air-cooled condensers may also penetrate airspace.
- **Communications Systems Interference** can be produced by either an electrical interference or as a physical obstacle between the communicator and a receiver. CSP structures can also obstruct or reflect radar signals
- **Visual Impacts from Glare and Glint**—Certain materials produce glint (a momentary flash of bright light) and glare (a continuous source of bright light), which can disrupt pilot and air traffic controller vision.
- **Thermal Plume Turbulence** is produced by power plants that employ a dry cooling system often referred to as an air-cooled condenser.
- **Vapor Plume Visual Impact** is typically produced by power plants, including CSP and peaking power plants, which utilize an evaporative wet cooling system.

<u>Mitigation Options</u>

- For parabolic trough plants, use nonreflective or diffuse materials or coating for bellows shields located every few meters at joints between heat collecting elements.
- The units should be rotated away from stow away position to ready position before sunrise to limit potential inadvertent glare. Parabolic designs should consider using end caps to reduce glare that "spills" from the ends of the trough.
- Curtailment in facility operations can be prescribed during periods when glare is expected to impact low-flying aircraft.
- Flight procedures can be restricted during certain periods of the day when glare may occur.
- County zoning ordinances may be put into place to limit glare-producing structures in airport influence zones.

WIND ENERGY

While there has been much interest in the wind power market for airports, there are significant issues between wind and aviation such as radar and mitigation that must be taken into account before wind turbine projects at airports are undertaken. Because of the extensive studies that wind turbines require, all proposals for wind turbines and met powers must be processed by the FAA's Obstruction Evaluation Group, and interested airports should utilize the Notice criteria Tool to determine if they are required to file an FAA Form 7460-1, Notice of Proposed Construction or Alteration.

<u>Wind Turbine Generator Basics</u> (Source: ACRP Synthesis 28, Investigating the Safety Impacts of Energy Technologies on Airports and Aviation)

Wind turbine generators (WTGs) convert air blowing across the earth's surface into electricity. The WTG's rotor is comprised of the rotor hub and typically three blades. Behind the rotor is attached a box called the nacelle, which encloses the turbine and other equipment necessary for generating electricity. The nacelle sits on top of a tower. The WTG is secured to the ground using concrete and/or bolt anchors depending on the composition of the substrate. WTGs may be sited as single units providing local power or in expansive wind farms comprised of hundreds of units that contribute electricity to the electrical grid. Utility-scale wind turbines constructed on land can be as high as 500 ft above ground level to the blade tip height. Large wind farms are connected to the grid through traditional electric transmission infrastructure comprised of transmission towers and high-voltage lines. Utility-scale wind turbines are operating in 37 states, with Texas, Iowa, and California the top three states in generating capacity.

Regulatory Review Processes:

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

<u>Notice Criteria Tool:</u>

https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm

If notice is required, the FAA Form 7460-1 may be submitted electronically on the website and should be filed 8-12 months before the planned construction date. Providing early notice will afford time for the FAA, DOD, and DHS to review proposals and engage in any negotiations.

Washington Dulles International Airport (IAD) Coordinates: 38° 57' 9.903'' N, 77° 26' 52.1808'' W (NAD83)

<u>DoD Preliminary Screening Tool (WIND)</u>

This tool enables developers to obtain a preliminary review of potential impacts to Long-Range and Weather Radars, Military Training Routes, and Special Airspaces prior to official Obstruction Evaluation/Airport Airspace (OE/AAA) filing. This tool provides a first level of feedback and single points of contact within the DoD/DHS and NOAA to discuss impacts/mitigation efforts on the military training mission and NEXRAD Weather Radars. This tool does not replace official FAA processes and procedures. https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp

<u>Results:</u>

- Air Defense and Homeland Security Radars (Long Range Radar): (Red) Impact highly likely to Air Defense and Homeland Security radars. Aeronautical study required.
- Weather Surveillance Radar-1988 Doppler radars (NEXRAD): Mitigation Zone—significant impacts are likely. NOAA will likely request mitigation if a detailed analysis indicates that the project will cause significant impacts.
- Military Operations: The preliminary review does not return any likely impacts to military airspace

Potential Impacts of Wind Energy Technologies

- **Physical Penetration of Navigable Airspace** as defined by FAR (Federal Aviation Regulations) **Part 77**—Structures rising more than 200 ft above ground level or less when located close to airports intrude on defined airspace
    - In most cases, the FAA will attempt to modify approvals before construction begins. Where construction has already occurred, the FAA is limited to making adjustments to flight procedures. For example, in the case of the Wild Horse Wind Farm in Washington State located 13 miles away from Bowers Airport (ELN), after the wind farm was constructed, the FAA flight procedures office assessed the potential impact of the constructed wind farm on instrument approach and missed approach procedures. It determined that the wind farm presented an Adverse Obstacle and raised the height above airport minimums from 421 ft to 801 ft.
    - Chain of communication breakdown can also occur. For example, in the Sheperd Flats review, the local Air Force base initially signed off on the project, when it required review from other people in the agency.
    - Although utility-scale wind turbines exceed 200 feet above ground triggering an airspace view, met towers often do notl. Met towers have been positioned at heights just under 200 ft, specifically to avoid triggering an airspace review and marking requirements. As a result, state agencies have expressed concern about the potentially undocumented hazard posed by met towers. The FAA issued a notice in 2011 recommending that met towers include alternate orange and white painting, and also seeks comments on sleeves around the guy wires to make the facilities more visible. Two weeks after the FAA's notice, a crop dusting aircraft hit a met tower in the Sacramento—San Joaquin River Delta of California and crashed killing the pilot. The met tower was 197 feet tall and therefore did not require airspace review or obstruction marking.
- **Communications Interference**—Electromagnetic interference can be caused by any large structure that can reflect radar signals causing loss of radar coverage "downstream" or produce false radar signals referred to as clutter. Physical structures can also obstruct view of navigational aids.
- **Turbulence Downward of Wind Turbine Rotors**—Wind turbines disrupt uniform air flow causing unseen turbulence produced downstream of wind turbines.

Mitigation Options

- Allow appropriate siting to avoid physical penetration and communication system impacts

- Provide developers with the opportunity to fund gap-fill radars or contribute to the cost of replacing long-range radar, thereby providing a dual benefit of allowing renewable energy development and upgrading aging radar systems.
- Re-route air traffic around the wind energy facilities to avoid potential shadow effects and disruptions associated with wind farm radar clutter as part of operational mitigation. Negative effects of an increased noise footprint and CO2 emissions from longer flight tracks need to be considered.
- Turn off radar that is receiving false returns for the wind farm areas and use supplemental radar that is available in the region but not affected by the clutter fill in the area of the wind farm by a technique called data fusion on the in-fill radar.
- Improve radar coverage for areas where low-level radar coverage is not required through physical or terrain masking.
- Use radar absorbent materials on WTG towers and nacelles to reduce the radar cross section of the structure that produces clutter. However, materials for use on blades has not been effectively developed, which is particularly problematic because the blades caused the greatest amount of interference.
- Fund collaborative research between government and industry on technical mitigation that collects additional information of existing wind turbine affects, designs parameters for gap-filler radar, characterizes wavelengths used in current radar systems to reduce signatures, and advances software processing.
- Develop new and modified radar facilities
- Create non-auto initiation zones (NAIZs) with some advanced primary radar plots that filter out tracks created by the wind turbines while not filtering out racks characteristic of aircraft.
- Create transponder mandatory zones (TMZs) that would allow SSR to provide full augmentation for primary radar.

Wind Turbine Impact Case Studies

1. Building-Integrated Wind Turbines:
    a. Honolulu International Airport: 16, 1kW units, 6’ x 8.5’’, electricity supplied to airport administrative building.
    b. Minneapolis-St. Paul International Airport: 10, 1kW units, Airport fire station
    c. Boston Logan Airport: 20, 1 kW units, Administration building
2. Vertical Axis Wind Turbines
    a. Martha’s Vineyard: 1 Sky Farm turbine, 50 kW, 20 feet tall, 14 diameter
    b. Detroit Metro: 6 windspire turbines, 1.2 kW, 30 feet tall, 4 feet diameter
3. Horizontal Axis Wind Turbine
    a. East Midlands Airport, UK: Second largest cargo airport in UK, Four 250 kW turbines, 130 feet tall, Powers 5% of airport’s needs, equivalent to 150 homes

Airport Solar/Wind Financing/ Energy Tools and Resources

Solar, Wind Power at Dulles Airport

1. NREL's PVWatts Calculator is a web application developed by the National Renewable Laboratory (NREL) that estimates the electricity production of a grid-connected roof or ground-mounted photovoltaic system based on a few simple inputs. To use this calculator, type in the address or geographic coordinates of the system's location, specify the system size and array orientation, and provide some information about the system's cost and electricity production, and for the monetary value of the electricity.

   Important Note. The PVWatts Calculator is suitable for very preliminary studies of a potential location for a photovoltaic system that uses crystalline silicon photovoltaic modules. The production estimates that PVWatts calculates do not account for many factors that are important in the design of a photovoltaic system. ***If you are using PVWatts to help design a system, you should work with a qualified professional to make the final system design based on an assessment of the system location and using more detailed analysis and design tools.*** http://pvwatts.nrel.gov/pvwatts.php On the website, there is more detailed information, and instructions on how to utilize this tool.
2. NREL System Advisor Model (SAM) is a performance and financial model designed to facilitate decision makingfor people involved in the renewable energy industry. SAM makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model. https://sam.nrel.gov/
3. CREST Cost of Energy Models: The Cost of Renewable Energy Spreadsheet Tool is an economic cash flow model designed to allow policymakers, regulators, and the renewable energy community to assess project economics, design cost-based incentives (e.g., feed-in-tariffs), and evaluate the impact of various state and federal support structures. CREST is a suite of four analytic tools, for solar (photovoltaic and solar thermal), wind, geothermal, and anaerobic digestion technologies. https://financere.nrel.gov/finance/content/crest-cost-energy-models
4. JEDI PV: The Jobs and Economic Development Impact (JEDI) Photovolatics (PV) model is a user-friendly tool that estimates the economic impacts of constructing and operating photovoltaic power generation at the local and state levels. https://jedi.nrel.gov/
5. Open PV: The Open PV Mapping Project is a collaborative effort between government, industry, and the public that is compiling a comprehensive database of photovoltaic installation data for the United States. Data for this project are voluntarily contributed from a variety of sources including utilities, installers, and the general project. http://pvwatts.nrel.gov/pvwatts.php
6. Technical Guidance for Evaluating Selected Solar Technologies on Airports (FAA) http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf
7. FAA Wind Turbine FAQs https://oeaaa.faa.gov/oeaaa/external/searchAction.jsp?action=generalFAQs
8. Part 77 https://www.faa.gov/air_traffic/publications/atpubs/AIR/air0603.html
9. Notice Criteria Tool https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm
10. ACRP Synthesis 28: Airport Cooperative Research Program: Investigating Safety Impacts of Energy Technologies on Airports and aviation http://onlinepubs.trb.org/onlinepubs/acrp/acrp_syn_028.pdf

CONCLUSION

Based on this preliminary research, we suggest pursuing a Solar PV system for Washington Dulles International Airport. It is important to note that because this research has not taken into account the specific design details and energy needs of IAD Airport, we cannot provide detailed recommendations. A wind turbine system may be feasible, but overall, solar energy seems to be a more convenient and safer option. A professional should inspect the airport to decide the most efficacious route to take. Projects must meet standards to protect air navigation and existing aviation activities, and support national environmental policies. Sponsors need to consider several factors to determine the feasibility of a solar project, including the consistency of a project with aviation activities and approved airport master plans, potential environmental issues associated with project siting alternatives, and the need to obtain approvals from the FAA. Sponsors should consult with the FAA early and throughout the process to ensure that a proposed project meets all FAA requirements.

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