Energy technologies' compatibility with airports and airspace: Guidance for aviation and energy planners

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Abstract

In response to economic, environmental and national security factors, nations are diversifying their energy extraction and generation opportunities through the development of cleaner, more efficient and renewable *technologies. These developments are expanding the geographic footprint of energy infrastructure and encroaching on the aviation transportation system. The aviation industry is concerned that current practices are not reducing the adverse impacts of energy projects on the safety of airport operations and navigable airspace. In response, the Transportation Research Board's Airport Cooperative Research Program (ACRP), an industry-driven, applied research programme of the National Academy of Sciences based in the USA, directed research to better understand the risk of airspace impacts from energy technologies and to develop best practices for aviation safety associated with planning, developing and constructing energy projects. The research focused on energy technologies that are currently being developed, including solar photovoltaic, concentrating solar power, wind power, oil and natural gas extraction, steam-generated power production and electricity transmission. Each technology produces different types of impacts on airports and navigable airspace including physical penetration of airspace, radar interference, glare and thermal turbulence. The research findings, drawing on information from Australia, the UK and the USA, are presented as best practices, organised by technology, and include general siting and design criteria for each. The Guidebook represents a comprehensive resource for aviation and energy industry professionals with information to improve energy technology siting to enable nations to meet domestic energy production needs while ensuring a safe and efficient aviation transportation system.*

Keywords

airspace, energy, glare, obstruction, radar

BACKGROUND AND METHODS

The energy industry is going through a transformation driven in part by public policy and sustained by technological innovation and market development.[1] Various energy technologies are already competing to meet this projected demand, including those powered by fossil fuels and renewable resources. Widespread use of hydraulic fracturing (ie 'fracking') and directional drilling for natural gas and petroleum, as well as technological advances in wind and solar energy, have dramatically increased energy supplies and reduced costs. Based on these trends, the US Energy Information Agency (EIA) projects natural gas, renewables and biofuels all to grow in their total share of US energy use with corresponding reductions in coal and petroleum use.[2] According to the Federal Energy Regulatory Commission (FERC), biomass, geothermal, solar, hydro and wind power accounted for 37 per cent of all new electric power generating capacity installed in 2013, which was down from 49 per cent in 2012.[3] Renewable energy accounted for 15.8 per cent of the US total capacity as of April 2013.

These changes have led to a geographical expansion in energy project deployment, increasing the potential for conflict with airports and airspace. ACRP Synthesis 28, 'Investigating Safety Impacts of Energy Technologies on Airports and Aviation',[4] provided a baseline review of the state of airport practice for the topic. The findings concluded that additional research is needed to further evaluate the safety effects that energy technologies may have on the air transportation system and to develop best practices to address such effects. The follow-on research was conducted under ACRP 02-38, 'Guidebook for Energy Facilities Compatibility with Airports and Airspace'.[5] This project provides a comprehensive review of the National Airspace System (NAS) and the potential effects of energy technologies on the NAS with best practices and guidelines for avoiding, minimising and mitigating impacts.

The Guidebook provides a thorough review of existing literature on airspace and energy technologies as a basis for assessing impacts followed by directed research to fill in data gaps. The airspace review defines the NAS[6] and describes its components from takeoff to landing, addresses the role of the US Federal Aviation Administration (FAA) in ensuring the protection of airspace as a public good, discusses airspace user types, and describes the future satellite-based airspace navigation system known as NextGen.[7] The energy technologies reviewed that have a potential impact on airports and airspace were solar, wind, oil and gas drilling, power plant stacks and cooling towers, and electricity transmission infrastructure. The potential impacts associated with these technologies are glare from solar power, radar interference and turbulence from wind power, physical obstructions and thermal heat from oil and gas drilling, thermal plume turbulence from power plants and physical obstructions from electrical transmission.[4] Some of these impacts are physical and, therefore, more readily quantifiable, whereas others, such as glare or turbulence, are non-physical and more difficult to define.

For this project, researchers collected information on the potential impacts of energy technologies on airspace by reviewing current regulation and policy from local, state and federal agencies, and discussed research and policy development being conducted by federal agencies and academia. In addition, information was obtained on the experience of airports in addressing the issues associated with specific projects, and some limited applied research was conducted to fill in some important data gaps. Interviews were conducted with US officials involved in energy and aviation planning and regulation at the Federal Aviation Administration, Department of Defense (DoD), Department of Homeland Security (DHS) and Department of Energy (DOE).[8] Visits were made with staff from the Dallas-Fort Worth International Airport (DFW) and Jimmy Stewart-Indiana County Airport to discuss natural gas drilling programmes on airport property and with Manchester-Boston Regional Airport and Rockford-Chicago International Airport to understand potential glare impacts from solar photovoltaic (PV) projects. Researchers participated in radar mitigation field testing programmes being conducted under a separate project facilitated by the DOE known as the Interagency Field Test and Evaluation (IFT&E) Program. Airports in the west Texas area near Abilene were contacted to collect information on the potential effects on air traffic from large wind farms and new electric transmission infrastructure. Laboratory testing of reflectivity from commercially available solar PV modules was performed and an online survey of pilots' experience with glare from airport solar PV projects was conducted. Industry associations including the American Wind Energy Association and the Solar Energy Industry Association were also contacted for coordination purposes. Presentations were made to their members describing the project, and information was collected on their experiences.

A review of the potential impacts of energy facilities on airports and airspace recognises the important role of energy and aviation to the country, including:

- The NAS, also critical to our national interests, is a finite resource that must be maintained and enhanced to ensure safe and efficient air travel.

- The expansion and modernisation of domestic energy development is central to our national interests.
- Energy and aviation are both critical to the future economic prosperity of the country.
- Energy impacts on aviation must be avoided, and impacts minimised and mitigated only when necessary.

NEW RESEARCH

The research showed that the intersection of energy and aviation has received a significant amount of attention over the past few years. The result has been the development of several new tools to help energy and aviation professionals improve the siting of energy projects, including those advocated by airports, to increase revenue for their airport business. While several areas requiring additional research remain, successful energy project siting will continue to depend on close coordination between project stakeholders and regulatory officials, combined with the utilisation of new knowledge related to aviation impacts from energy technologies and new tools for measuring and minimising these impacts. Some of the new information generated during the project included the measurement of solar PV module reflectivity and surveying pilot experience with glare from solar PV systems.

Measuring solar PV reflectivity

Sandia National Laboratories conducted solar PV module reflectivity testing as part of this project to improve understanding of the potential for solar to produce glare.[8] The total solar reflectivity generally ranged from 6 to 12 per cent, whereas the specular solar reflectivity ranged from approximately 1 to 4 per cent. One PV module surface glass, referred to as deep-textured glass, did not show any measurable specular reflectance, which indicates a significant amount of scattering of the reflected light relative to smooth or lightly textured surfaces. Smooth surfaces such as mirrors and smooth glass produce more specular reflections with greater intensity and tighter beams (ie larger retinal irradiances and smaller subtended angles), whereas solar receivers, textured glass and anti-reflective coatings produce more diffused reflections with lower solar intensities but greater subtended angles. It is important, however, to note that these values are for an incidence angle of 20 degrees. At higher incidence angles, the reflectivity can increase significantly. While these data are not yet ready to be directly applied to the Guidance, it does suggest that use of the deep-textured panels at airports may be a siting option for PV to minimise potential glare at sensitive airport receptor locations (ie air traffic control towers and pilots on arriving aircraft).

Surveying pilot experience with glare

An online flight crew survey was designed and distributed to obtain empirical information from pilots on the sources of their experience with solar glare in general and solar power facilities specifically.[8] Commercial airline and general aviation pilots completed the survey with 383 total pilots responding. The Airline Pilots Association and the Aircraft Owners and Pilots Association cooperated in the communication and distribution of the survey. A summary of the results is provided below.

Thirty-two per cent of the respondents operate primarily at airports with known solar energy facilities. Of the pilots who stated that they have experienced solar glare, they noted the following potential glare sources:

1. Sun at sunrise or sunset: 83 per cent;
2. Bodies of water: 57 per cent;
3. Glass buildings: 37 per cent;
4. Windows: 26 per cent;
5. Building roofs: 17 per cent.

When asked how they normally deal with glare, most pilots stated that they adjust shading in the cockpit (83 per cent) and use sunglasses (75 per cent). Many pilots noted that they attempt to alter their direction of view (48 per cent), whereas others said they wear baseball-style hats, adjust their seat height or simply use their hands to the block glare. Forty-five per cent of respondents stated that they were aware of solar power facilities at airports at which they operate. While 44 per cent were uncertain of the type of technology observed, 31 per cent said they observed concentrating solar power (CSP) and 25 per cent observed solar PV technology. Nine per cent of respondents who were aware of solar projects indicated that they had experienced glare, whereas 74 per cent did not. Of the pilots who did experience glare, 4 per cent classified the glare as a 'significant nuisance', 24 per cent as a 'moderate nuisance' and 72 per cent as 'not a nuisance'.

Wind power and radar

Contemporary wind turbines have a blade tip height up to 500 feet above ground level (AGL) and heights may continue to increase. Given that defined airspace technically begins at 200 feet AGL, most wind turbines constructed in the US have an impact on aviation. The core concept of radar requires the transmission of energy pulses from the antenna in a known direction. A 'target' reflects some amount of that energy (ie a 'return') back to the antenna where it is received and processed before it is displayed on an operator's panel as a target. The time the energy takes from initial antenna pulse to the time it is received provides the distance (ie 'range') to the target. The presence of large structures across the landscape can obstruct the transmission of radar signals. The wind power industry has been working with the US government, military and commercial aviation to assess the potential impacts of wind turbines on radar for close to a decade.

The DOE recently collaborated with the DoD, DHS and the FAA in sponsoring the IFT&E Program to validate commercial off-the-shelf (COTS) technologies with the potential to mitigate electromagnetic interference from wind turbines on radar systems.[9] While the results of this research were not fully available to inform siting guidelines, the familiarity with the research and the type of information it will be providing supported the presentation of credible mitigation options.

TECHNOLOGY SUMMARY

As part of the research, the project team collected information associated with each energy technology type to support guidance for future projects. The information on guidance varied significantly among the technologies. For some, like solar PV and oil and gas drilling, the guidance was based on FAA guidance and supported by the experience of specific airport projects. For others, like wind power and steam-generated power, the guidance was based on evolving research that has not yet been completed. The following section presents a summary of guidelines for each technology.

Solar

Guidance for solar PV is based on the FAA's 'Technical Guidance for Selected Solar Technologies',[10] also referred to as the Solar Guide, and the 'Interim Policy for Review of Solar Energy Systems on Federal Obligated Airports'.[11] The Solar Guide provides background on the issues that must be addressed to avoid impacts on airspace. The Interim Policy requires airport sponsors to utilise the Solar Glare Hazard Analysis Tool (SGHAT)[12] or an approved alternative to assess the potential ocular hazard from a solar project. Additionally, while low-glare glass may not be an explicit project requirement, research for this Guidebook suggests that airports considering solar projects should request feasibility assessments for the use of low-glare glass to mitigate glare in the Requests for Proposal (ie bid solicitation).

Wind

Wind power development has been expansive due to its potential to produce a significant amount of renewable energy and achieve public policy mandates for renewable energy. High demand to construct wind projects has forced aviation and military stakeholders to respond to encroachment on the NAS, garnering wind energy installations close scrutiny since at least 2006.[13] Project development is subject to a review process facilitated by the FAA and contributed to by the military and other government agencies with a variety of interests.[14] The UK Civil Aviation Authority has also developed guidance.[15] Through each process, individual projects must demonstrate how they are avoiding and minimising impacts on airspace and, if required, how they will mitigate for unavoidable impacts. Approvals have sometimes demonstrated a compromise where in some cases airspace around the wind farm is restricted and in other cases radar facilities are upgraded as part of project mitigation.

The DOE, DoD, DHS and FAA have taken lead roles in advancing this process, as evidenced by the IFT&E Program and its focus on developing radar mitigation technologies that can be deployed throughout the country. Interagency coordination, building on successful projects like the DoD Siting Clearing house, will be important for avoiding and mitigating potential problems early in the siting process.[16]

Oil and gas

The development of oil and gas programmes at several existing airports provides useful information for considering best practices and guidance.[17,18] The flaring of wells has been a difficult impact to measure because the influence of flames and associated heat is variable and not well defined. Moreover, energy companies have alternative methods to achieve the same result. DFW does not allow flaring, so the drilling company is required to either (1) shut the well until regulator valves are installed or, if applicable, (2) run the gas through pipeline connections from the lateral pipelines into the main pipeline system.

Frack ponds are also a concern from a wildlife-attractant perspective. At some airports, like Jimmy Stewart in Indiana Pennsylvania, frack ponds have been constructed as temporary facilities to support the drilling operations and then returned to their pre-existing condition. In other cases, frack ponds have been retained at the facility to support future well development. Permanent facilities have been designed to include wildlife-discouraging attributes that may be useful for future projects, such as those at DFW. The development and implementation of the DFW Oil and Gas Program also offers lessons in the level of coordination with the FAA necessary to efficiently review and determine potential impacts on airspace of a variety of temporary and permanent structures associated with drilling and how to successfully manage the impacts.

Power plant stacks and cooling towers

The issue of thermal plume impacts on small fixed-wing aircraft and helicopters represents another example of a non-physical intrusion of airspace that is difficult to measure and therefore difficult to establish significance criteria.[19] A recently released report from MITRE concluded: 'while it is unlikely that an aircraft will reach upset criteria, there is a definite risk of light aircraft experiencing severe turbulence within the TLS [target level of safety] as they fly above an exhaust plume emitted from a power plant or other industrial facility in certain weather conditions.'[20] There are numerous documented incidents of pilots reporting turbulence when flying over exhaust stacks.[21] No specific regulatory criteria in the US, however, have been developed to address plumes from exhaust stacks due to the difficulty of characterising impacts. Australia's Civil Aviation Safety Authority (CASA) identified the need for plume hazard evaluations and developed a methodology through an Advisory Circular in 2004, which was recently updated in 2012 to account for new criteria to address 'severe turbulence' and 'loss of control' to an aircraft.[22] Since the CASA guidance is the only formal regulatory criteria in use to address thermal plume impacts on aircraft, it will likely be used by other regulatory bodies when evaluating potential effects. As power plants are large structures visible in the landscape, the clearest guidance is to avoid flying over power plants especially when flying at low altitudes, and to be aware of potential turbulence in the area from exhaust stacks as this turbulence can be either visible or not visible, depending on weather conditions.[23]

Electrical transmission

The topic of transmission line development and airspace impact illustrates a few key points.[24] First, as transmission lines have been constructed in the same manner for over 100 years (ie power lines attached to utility poles), many such obstructions exist near airports. Aircraft are alerted to these obstructions when reviewing information and procedures for specific airports and some areas are being mitigated over time. A variety of mitigation options are available to address existing problem sites, including making physical modifications (eg lowering the height or burying the lines), placing lights or signal ball markers on the lines or poles, or increasing minimum altitude standards.[25] In addition, some transmission projects may not be reviewed by the FAA or aviation stakeholders, so those obstructions may not be identified until project construction occurs and impacts are observed. This suggests the importance of airports and local stakeholders maintaining awareness of electricity transmission development projects in the area of airports and referring any potential issues to the FAA's Regional Office or ADO.

DISCUSSION

The main purpose of the Guidebook is to present best practices for aviation safety associated with planning, developing and constructing energy production and transmission technologies at and around airports. Fulfilling this objective was a challenge, given the variety of technologies and types of impacts, as well as the general lack of performance standards available for assessing impacts. To meet this challenge, a set of concise guidelines and practical considerations for siting and managing energy projects in the aviation environment was presented in two formats. The first section lists best practices for each energy technology, allowing users to quickly review issues particular to a proposed project. The second section includes general guidance for siting structures to avoid physical obstructions based on the height of the structure, as well as other design observations for each energy technology type.

The research revealed some general conclusions about the difficulty of assessing potential impacts on airports and airspace. While not exclusive to energy technologies, they are an important part of assessing aviation safety impacts from energy and identifying best practices and guidelines, including:

- It is not a complicated process to determine if a structure results in a physical impingement of airspace; however, it is difficult to determine if the physical impingement results in a significant impact.
- Structures that do not result in a physical impingement of airspace may still pose a significant risk to aviation.
- Non-physical impacts (eg glare and turbulence) are not well defined, making it difficult to develop associated guidance.
- FAA has direct authority to review on-airport energy projects but may not have authority over many off-airport projects.

The Guidebook summarises a number of new research initiatives, some of which were conducted as part of or in association with this project, and others that were entirely independent. These research efforts were used to inform best practices and guidelines, including the following:

- Glare measurements from commercially available solar panels;
- Glare modelling and model verification;
- Survey of pilots on their experience with glare;
- Wind turbine radar research, conducted under the IFT&E Program;
- Development of new wind power and thermal plume turbulence modelling tools;
- Survey of airports located proximate to new electrical transmission infrastructure.

CONCLUSION

An expansion in national energy production catalysed by advances in extraction and generation technologies and public policy programmes toward cleaner and more efficient sources has led to increasing conflicts with aviation activities. In some cases, airports have sought to use property assets to develop energy as an alternative revenue source or to provide cost savings to sustain the airport business. While it was not possible to identify simple numeric guidance for siting each of the energy technologies to avoid impacts, the 'Guidebook for Energy Facilities Compatibility with Airports and Airspace' is a valuable resource for energy and aviation planners in that it provides a comprehensive review of the issues involving the potential impacts of energy technologies on airspace, summarises the status of policy and regulation, identifies issues that require additional research, and provides new data to improve project siting. It also demonstrates a significant amount of progress that has been made in promoting clean energy development that is compatible with airports and airspace.

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