SOLAR PHOTOVOLTAIC ENERGY FACILITIES: ASSESSMENT OF POTENTIAL FOR IMPACT ON AVIATION

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1. Introduction

1.1 This report assesses the potential impact of solar photovoltaic energy facilities located in off-airfield situations. This report was commissioned by RPS Planning & Development on 4th January 2011.

1.2 This study is also limited to considering photovoltaic (PV) panel technology. Other solar energy technologies such as concentrating solar and parabolic trough raise different issues in relation to aviation and are not considered here.

2. Generic aviation issues generated by PV technology

2.1 PV technology generally consists of flat panels covered with specially-manufactured glass which is designed to maximise absorption of light and minimise reflections. PV technology is deployed in two main forms:

- roof-mounted panels providing electricity to buildings
- stand-alone 'farms' of up to several thousand panels, supplying electricity to the grid.

2.2 PV panels are unlikely to have sufficient stand-alone height to constitute a physical collision hazard to aircraft.

2.3 PV panels do not generate sufficient electromagnetic energy to act as a source of electromagnetic interference other than at very short range in the immediate vicinity of the panels. Transformer units at a PV panel site may generate electromagnetic fields in their immediate vicinity but these are subject to normal established standards for minimising electromagnetic interference around any electrical facility.

2.4 The potential for glare (which may act as a distraction to pilots) caused by sunlight reflected off the panels is the only significant aviation issue likely to be raised by PV panels.

3. Regulatory provisions

3.1 In the USA, the Federal Aviation Administration published its first guidance on the use of solar energy technologies around airports in November 2010.[1] Chapter 3 of that document lists glare as one of the potential hazards of solar technologies on or near airports. It should be noted that the FAA guide specifically addresses solar technology on or near airports; it does not address any issues arising from solar energy facilities not located in the vicinity of an airport.

3.2 The FAA study notes that, while solar collector technology has highly reflective surfaces, PV technology is primarily absorptive since the purpose of

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[1] FAA, *Technical Guidance for Evaluating Selected Solar Technologies on Airports*, FAA-ARP-TR-10-1, November 2010.FAA-ARP-TR-10-1, November 2010.

the PV panel is to absorb as much of the sun's energy as possible. The study notes that the degree of reflectivity of a PV panel will depend upon:

- the intensity of the incoming light
- the reflectivity of the panel surface
- whether the reflected light is 'specular' (as occurs from mirrors and still water) or diffuse (as occurs from rough surfaces such as terrain and vegetation) – see Figure 1.

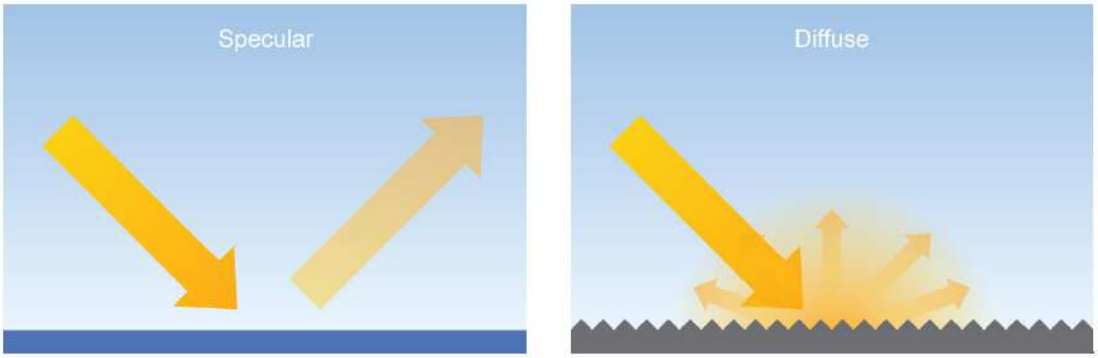


Figure 1: Specular vs diffuse reflections [Source: FAA]

3.3 The FAA guidance suggests that reflected light from a PV panel is primarily specular in nature, and that evaluation of impacts be conducted by one or more of the following methods:

- qualitative analysis of potential impact in consultation with the airport authorities
- a demonstration field test with solar panels at the proposed site in coordination with airport personnel
- geometric analysis to determine the days and times when an impact is predicted.

3.4 The FAA guidance lists eight solar power projects at or adjacent to airports in the USA which have completed FAA assessments. In all of these cases the FAA either determined that a full review was not required, or reached a finding of No Hazard. Further details of these are set out in Section 6 below.

3.5 Following the publication of the FAA guidance, the UK Civil Aviation Authority (CAA) issued interim guidance on the impact of solar photovoltaic systems on aviation in December 2010. Following internal review of the FAA guidance, the CAA will issue formal policy and guidance on this issue, including the impact of systems deployed further than 15km away from aerodromes.

3.6 The interim CAA guidance notes that the "key safety issue is perceived to be the potential for reflection from SPV to cause glare, dazzling pilots or leading them to confuse reflections with aeronautical lights" and refers to UK air law provisions relating to distraction of pilots by lights and other factors.

3.7 The interim CAA guidance does not contain any specific recommendations on the control of solar photovoltaic (SPV) developments away from airfields, but notes that the operators of licensed aerodromes may consider setting up procedures which only require consultation on SPV developments within 5km radius, or within the visual circuit of the aerodrome. In addition the CAA recommends that "as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests." It is expected that the CAA's formal guidance, when it is published, will recommend an assessment methodology similar to that advised by the FAA (see 3.3 above).

3.8 Generic guidance on the three suggested approaches to assessment of SPV installations are set out in the following sections.

4. Glare analysis

4.1 The review of aviation experience with solar energy technology (see Section 6) indicates that any concerns have focused on solar facilities on or adjacent to airfields. From this evidence, off-airfield ("en route") facilities are unlikely to present glare/dazzle problems to pilots, for the following reasons:

- dazzle/glare is likely to present a hazard only during critical phases of flight, especially approach and landing; the en route phase is not normally a critical phase
- dazzle/glare occurs almost exclusively at low angles of elevation; aircraft in the en route phase of flight will be at higher angles of elevation
- pilots in the en route phase are already subjected to glare from a number of existing sources such as large assemblies of parked cars, major glasshouse facilities and large bodies of water; these are not considered to require analysis and mitigation despite having potentially much higher luminosity values than PV panels
- the pilot view from most cockpits, particularly in the forward direction, is severely limited in the downward direction by the aircraft structure, thus blocking the line of sight to any source of glare on the ground.

4.2 In the light of the above, it is unlikely that a glare analysis would be required for any solar facilities in the en route environment. However, in the event that such an analysis was required, it should take into account the following principles.

4.3 PV panels are constructed from specially-treated low-iron glass, designed to minimise reflection and maximise transmission of light through the glass. Standard low-iron glass reflects approximately 7% of light. As an example, Sunarc AR-Glass panels reflect a total of approximately 2% of the light (see Figure 2).

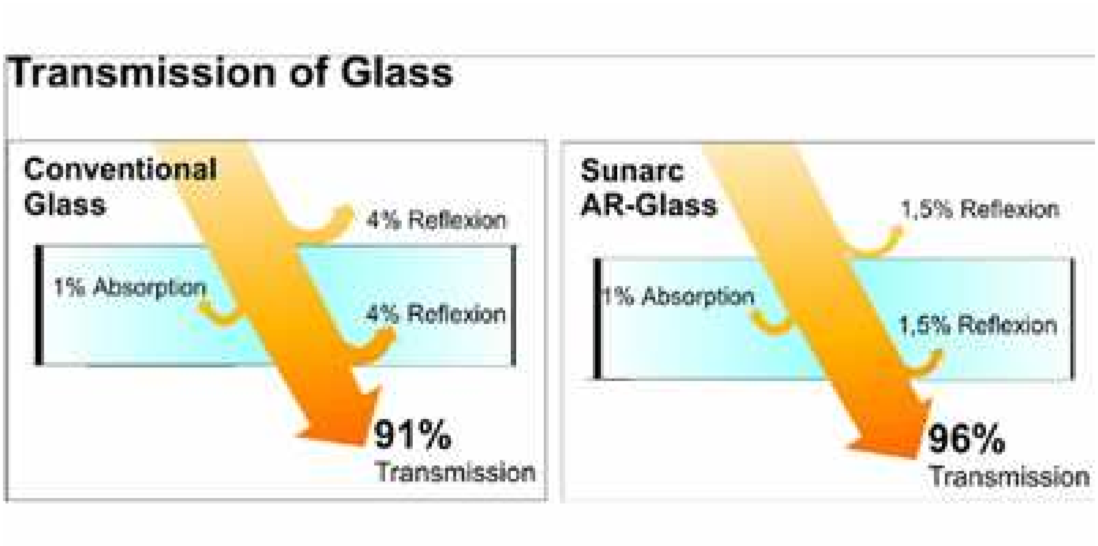


Figure 2: Reflectivity values[2]

4.2 These values are significantly lower than the reflectivity of other building materials. Figures 3 and 4 provide comparisons of the reflectivity of different materials.

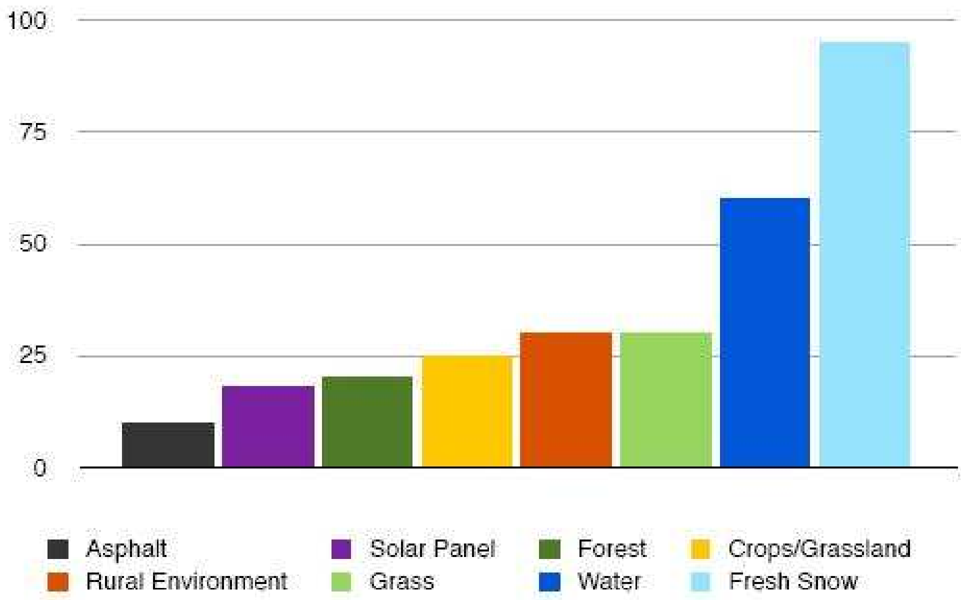


Figure 3: Comparative reflection analysis

[2] From http://www.sunarc.net/index.php?option=com_content&view=article&id=26&Itemid=24

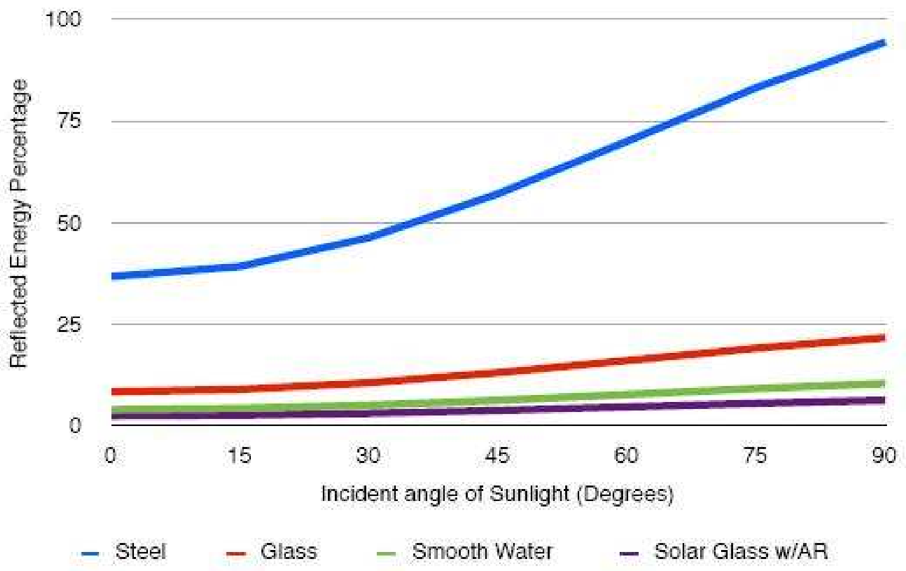


Figure 4: Analysis of typical material reflectivity with sunlight angle[3]

4.4 It should also be noted that, because glare from solar panels will only be reflecting some 2% of the light, the intensity of any glare will be a great deal less than the glare from direct sunlight, as would be experienced, for example, when flying directly towards a low sun. The latter manifests itself in particular at airfields with south-westerly oriented runways, for pilots flying an approach in the late afternoon in winter, directly into a low sun. In these circumstances impairment of vision due to direct glare from the sun can be compounded by specular reflection of the sunlight from a wet runway surface. Evidence of this can be found in Section 7 of this report, which considers data on glare as a factor in aircraft accidents in the UK and USA.

5. Geometric study

5.1 In order to assess the probability of glare from an SPV installation occurring to pilots of aircraft flying in the vicinity, a study can be carried out of the frequency with which specular reflections off the panels would be oriented towards aircraft on specified routes or at key points. However this is unlikely to be required for off-airfield solar facilities, for the reasons set out above.

5.2 If required, a geometric study may be carried out as follows:

- calculation of the incidence of reflections to an aircraft at a specified position or positions
- nature of the reflection source (multiple or single surfaces)
- whether the reflections are assumed to be specular or diffused
- panel orientation in azimuth and elevation
- sun azimuth and elevation angles for the SPV site for specified periods (these can be obtained from the US NOAA Solar Position Calculator[4]

3 Capital Solar Farm Visual Impact Assessment, September 2010, http://majorprojects.planning.nsw.gov.au/files/62450/Capital%20EA%20Final%201.0%20Appendix%20F_compressed-_Part4.pdf

4 http://www.srrb.noaa.gov/highlights/sunrise/azel.html

6. Experience from existing solar energy projects

6.1 Solar energy facilities have operated at and adjacent to airports and airfields for more than 20 years. The bulk of the experience is in the southern and western states of the USA. Table 1 summarises projects adjacent to airports around the world. In reviewing this experience, requests for information, including any examples of pilot reports of distraction by glare from the facilities, were submitted to airport and solar energy facility operators in Germany and the USA. No instances of such pilot reports were found.

6.2 It should be noted that the experience summarised in Table 1 relates to all types of solar technology - concentrating solar, roof-mounted systems and both fixed and tracking stand-alone arrays.

6.3 The fixed solar PV array at Oakland International Airport has been operational since November 2007. This was only approved after full FAA analysis and approval, including consideration of the potential for glare to affect not only pilots, but also controllers (the control tower is located a short distance east of the array). Since the facility became operational there have been no reports of glare from pilots or controllers. It is notable that this facility is located directly under the final approach for Oakland's runway 33. Because of the relative orientation of the facility relative to the sun and approaching aircraft, there is a high probability of specular reflections from the panels being directed towards aircraft on final approach, a phase of flight when pilot distraction could have significant safety implications. Appendix 1 shows the location of the PV array on the airport diagram. Figure 5 shows the location from Google Earth.

6.4 The Fresno Airport development is also located in the final approach area for one of the airport runways. This is shown in Figure 6. The Planning Manager for Fresno Airport has confirmed that there have been no complaints from pilots or controllers and has written to the developers of another solar scheme in the USA stating that "reflectivity is not an issue for aviation" (see Appendix 2).

6.5 The PV array at Meadows Field airport, Bakersfield, California, is located adjacent to the main taxiway between the terminal apron and the runway (see Figure 7). The array is on the north side of the airport, thus creating a high probability of any reflections of sunlight affecting aircraft. The Director of Aviation for Kern County, the owners of the airport, has confirmed that the development was only approved after onsite tests and discussions with FAA officials, and that no reports of problems from glare have been reported.

6.6 It should be noted that all of these projects are located in US states with very high duration and intensity of sunlight, exceeding those in virtually all European countries.

Table 1: Existing solar energy facilities at/adjacent to airports			
Site location	*Type of facility*	*Aviation facility*	*Reported impacts*
Kramer Junction, Victorville, CA, USA	Concentrating solar	Kramer crop-dusting strip; Edwards Air Force Base	None reported in 20 years of operation
Blythe, CA, USA	Parabolic trough concentrating solar (1000MW)	Blythe Airport (one mile south)	No information (approved Sept 2010)
Pena Boulevard, Colorado, USA	Tracking PV arrays	Denver International Apt	FAA finding of No Hazard
Denver Airport, Colorado, USA	Fixed PV arrays	Denver International Apt	FAA finding of No Hazard
San Francisco Airport, CA, USA	Roof-mounted PV panels	Commercial airport	FAA finding of No Hazard
Fresno Airport, CA, USA	PV arrays	Commercial airport	FAA finding of No Hazard
Bakersfield, CA, USA	PV arrays	GA airport	FAA finding of No Hazard; no pilot reports of glare
Oakland Airport, CA, USA	Fixed PV arrays	Commercial airport	FAA finding of No Hazard; no pilot reports of glare
Albuquerque Airport, NM, USA	Roof-mounted PV panels	Commercial airport	No information
Boston Logan Airport, MA, USA	Roof-mounted PV panels	Commercial airport	No information
San Jose Airport, CA, USA	Roof-mounted PV panels	Commercial airport	No information
Houston Airport, TX, USA	Roof-mounted PV panels	Commercial airport	No information
Ben Gurion Airport, Israel	Roof-mounted PV panels	Commercial airport	No information
Adelaide Airport, Australia	PV panels on terminal building	Commercial airport	No information
Prescott Airport, AZ, USA	Fixed & tracking PV arrays	GA airport	No information
Munich Airport, Germany	Roof-mounted PV panels	Commercial airport	No information
Yuma Airport, AZ, USA	Roof-mounted PV panels	Commercial airport	No information

Figure 5: Location of solar PV array at Oakland Airport

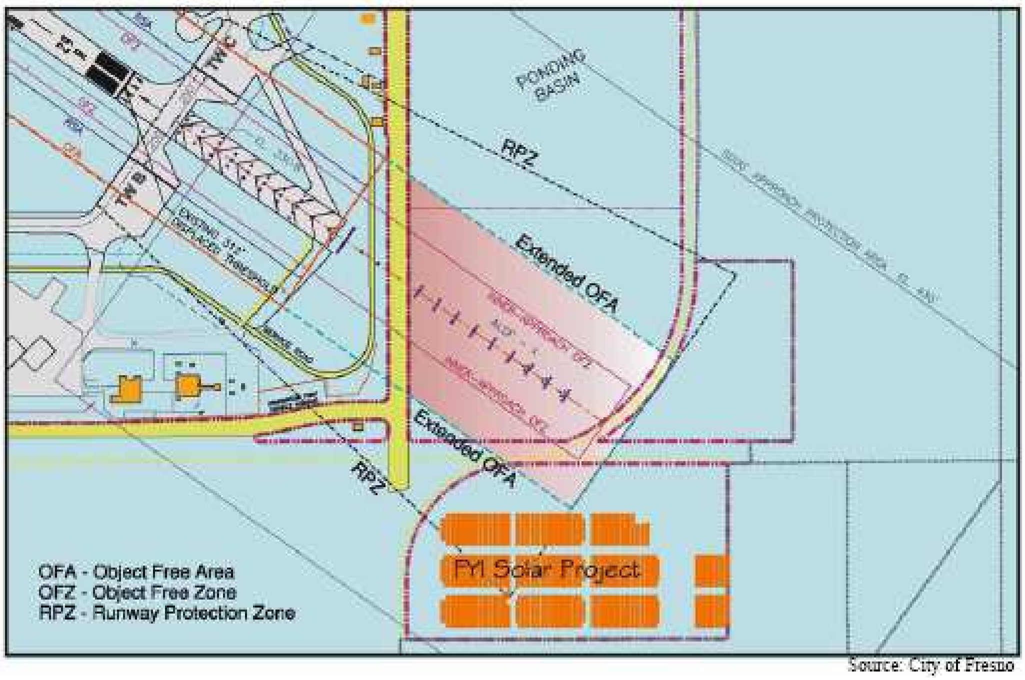


Figure 6: Location of solar PV array at Fresno Airport

Figure 7: Bakersfield Airport showing location of solar array

7. Evidence from accident data

7.1 Searches have been conducted in the online aircraft accident databases of the UK Aircraft Accident Investigation Board (AAIB) and the US National Transportation Safety Board (NTSB) for accidents in which 'glare' was cited as a factor in the period 2000 to 2010.

7.2 The UK AAIB database contains three cases:

- a Chipmunk which struck a parked PA28 at Prestwick in 2007 while taxi-ing directly into a low sun
- a Maule which struck a parked aircraft on landing at Top Farm, Cambridge, in 2005 while landing directly into the setting sun
- a Cessna 182 which made a heavy landing at Derby in 2005 when the pilot became dazzled by the low sun during the flare.

7.3 There were no cases in the AAIB database of incidents caused by glare other than directly from the sun.

7.4 The NTSB aviation accident database for the period 1 January 2000 to 30 November 2010 contained 133 records matching the search term 'glare'. These were analysed individually to eliminate those where the reference to 'glare' related to the term 'glare shield', to glare from lights on the ground during night flight, or to a finding that 'glare was not a factor'.

7.5 There were 66 remaining cases where a contributing factor in the accident was glare. Of these, 59 were recorded as involving direct glare from the sun, typically during a landing approach or low level flight directly into a low sun. One was recorded as a taxi-ing accident due to glare from sunlight reflected off a car windshield; three involved commercial aircraft mistakenly landing on a taxiway at Seattle due to sun glare reflecting off wet paved surfaces during the approach to land; two involved glare from the water while landing in a floatplane; and one involved sunlight from behind the aircraft appearing to illuminate the 'gear down' indicator light. There were no cases of accidents in which sun glare from any other objects such as solar energy facilities was cited as a factor.

7.6 It can be concluded that there is no evidence from UK or US records of glare from solar energy facilities as a factor in aircraft accidents.

8. Summary and conclusions

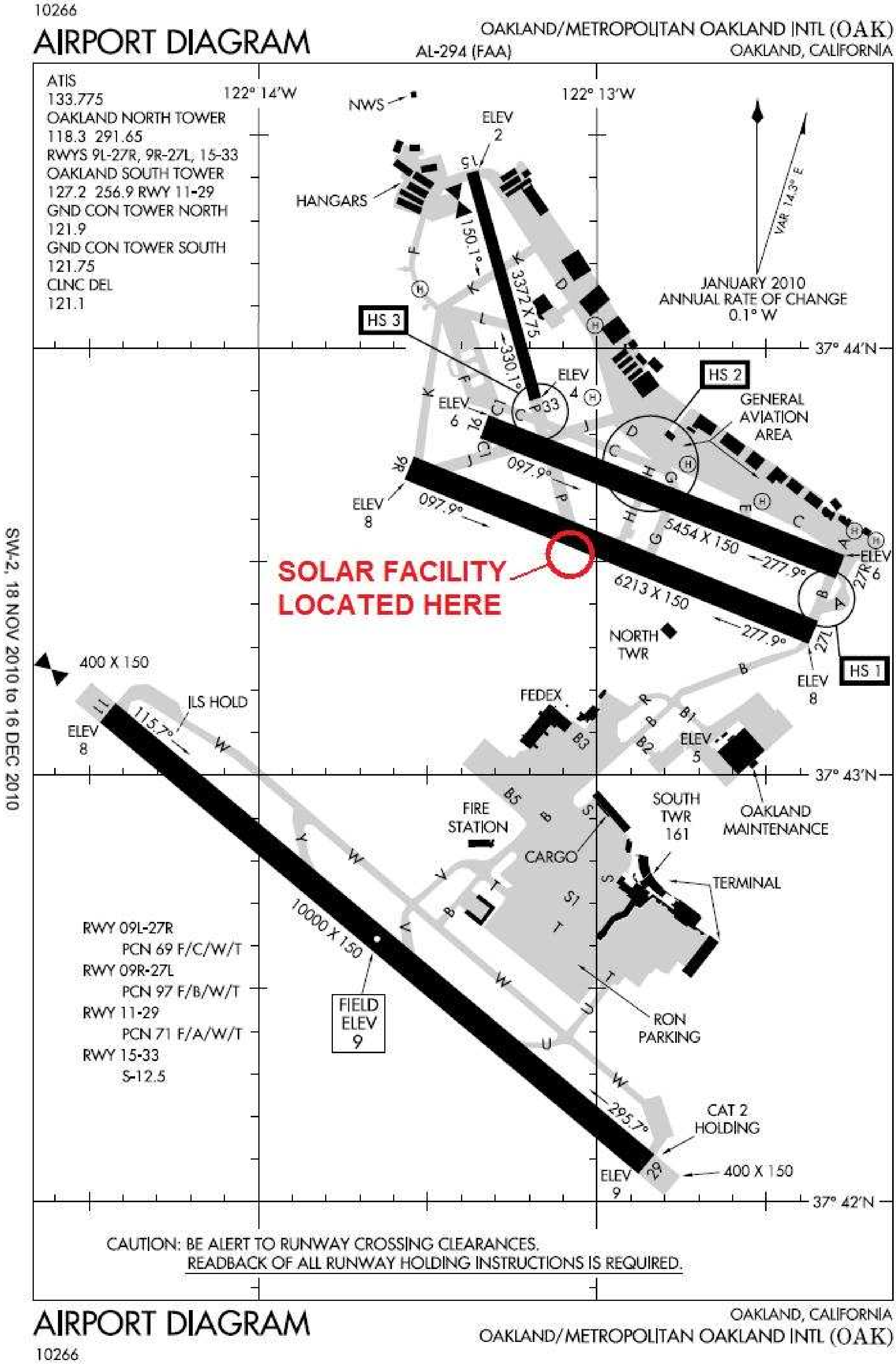
8.1 The potential for glare or dazzle to pilots caused by sunlight reflected off solar photovoltaic panels is the only significant aviation issue likely to be raised by this technology.

8.2 Solar photovoltaic panels are designed to absorb rather than reflect light. Typical panels are designed to reflect only some 2% of incoming sunlight. Reflected light from solar panels will have a significantly lower intensity than glare from direct sunlight.

8.3 Solar energy facilities located away from the vicinity of airfields are unlikely to present problems of glare to pilots.

8.4 No evidence could be found from existing solar energy projects around the world of any reported problems of glare affecting pilots. This includes many projects in the USA where the Federal Aviation Administration routinely assess such projects for potential glare impacts.

8.5 UK and US aircraft accident databases contain no cases of accidents in which glare caused by a solar energy facility was cited as a factor.


10266
AIRPORT DIAGRAM
AL-294 (FAA)
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OAKLAND, CALIFORNIA
ATIS
133.775
OAKLAND NORTH TOWER
118.3 291.65
RWYS 9L-27R, 9R-27L, 15-33
OAKLAND SOUTH TOWER
127.2 256.9 RWY 11-29
GND CON TOWER NORTH
121.9
GND CON TOWER SOUTH
121.75
CLNC DEL
121.1
122° 14'W
122° 13'W
NWS
ELEV 2
HANGARS
JANUARY 2010
ANNUAL RATE OF CHANGE
0.1° W
VAR 14.3° E
HS 3
HS 2
HS 1
37° 44'N
37° 43'N
37° 42'N
150.1°
3372 X 75
330.1°
GENERAL AVIATION AREA
097.9°
5454 X 150
277.9°
6213 X 150
SOLAR FACILITY
LOCATED HERE
NORTH TWR
400 X 150
ILS HOLD
115.7°
FEDEX
OAKLAND MAINTENANCE
SOUTH TWR 161
FIRE STATION
CARGO
TERMINAL
10000 X 150
FIELD ELEV 9
RON PARKING
295.7°
CAT 2 HOLDING
RWY 09L-27R
PCN 69 F/C/W/T
RWY 09R-27L
PCN 97 F/B/W/T
RWY 11-29
PCN 71 F/A/W/T
RWY 15-33
S-12.5
SW-2, 18 NOV 2010 to 16 DEC 2010
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.
AIRPORT DIAGRAM
OAKLAND, CALIFORNIA
OAKLAND/METROPOLITAN OAKLAND INTL (OAK)
10266

FRESNO YOSEMITE
INTERNATIONAL AIRPORT

City of Fresno Airports Department

February 22, 2010

Tanya Martinez
US Solar
PO Box 44485
Phoenix, AZ 85064

SUBJECT: Photovoltaic System at Fresno Yosemite International Airport (FAT)

Dear Ms. Martinez:

In 2008 a 2 megawatt PV system was brought on line at FAT. The system is located on a 20 acre parcel of airport land approximately 1500 feet from and within the approach zone of our primary runway. During the design process the issue of reflectivity was vetted to the fullest extent possible at that time. The research involved (i) discussions with various PV manufacturers, (ii) study of other PV systems in close proximity to an airport, and (iii) a complete FAA 7460 airspace review of our PV project. Our research, which was supported by the FAA through the 7460 process, determined that PV panels do not create glare or any other hazard to aircraft. The PV system at FAT was one of the first and is the largest single installation at any airport in the United States. To date, there have been no complaints from any pilot or the FAA Tower. In addition, a second 1 megawatt PV system was installed off airport (approximately 3000' north and abeam the primary runway). This system also went through the FAA 7460 process and has now been operational for over 12 months with no pilot or FAA Tower complaints. These installed systems have reaffirmed our finding that reflectivity is not an issue for aviation and dispels the common misconception that PV panels create glare.

From an airport perspective, we have enjoyed the benefit of using renewable power for 58% of our total demand and have realized financial savings within the first year of operation. The PV system at FAT is big part of our ability to remain self sustaining and meet the financial obligation of our federal grant assurances.

Please feel free to forward this letter on to whomever you feel can benefit from this information. If there are any further questions regarding our solar PV installation, feel free to contact me at 559-621-4536 or kevin.meikle@fresno.gov.

Sincerely,

Kevin Meikle,
Airports Planning Manager

Cc: Riverside County ALUC
Kimchi Hoang, FAA Western Pacific Region

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